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EDITORIAL.

DR. H. W. Jack, M.B.E., B.A., D.Sc., formerly of the Federated Malay States, arrived in the Colony on September 9th and took over the duties of Director of Agriculture. The Staff takes this opportunity of extending to him a cordial welcome.

Mr. A. B. Ackland paid a short duty visit to New Zealand, leaving on September 13th and returning on October 5th.

Mr. C. R. Turbet, Senior Veterinary Officer, proceeded on long leave to England on August 3rd.

Mr. W. J. Blackie, Government Chemist, returned from leave on June 1st.

Mr. H. R. Surridge, Agricultural Officer, proceeded to England on long leave on March 16th.

Mr. T. H. C. Taylor, Coconut Committee Entomologist, proceeded to England on May 5th on leave, prior to retirement. We are informed that he has received an appointment in Uganda, and offer the best wishes of this Staff.

Mr. H. M. Stuchbery, Government Veterinary Officer, was transferred from Nadi to Suva, and Mr. C. H. Koster was transferred from Suva to Nadi on July 17th.

Mr. B. Lyon Field, who has been temporarily in charge of the Rice Mill, returned to Lautoka to resume his duties as Cotton Inspector.

Mr. B. F. Hooper, Assistant Agricultural Officer, was transferred to the Constabulary.

Mr. N. G. J. McNally, Stenographer, was transferred to the Attorney-General's Department as from November 1st.

Miss V. H. McHugh, Laboratory Assistant, Entomological Division, returned from leave on September 25th.

AGRICULTURAL SHOWS, SUVA AND SIGATOKA.

THE Annual Fiji Agricultural Show was held in Suva on the 8th of October, 1934, and the Department was represented by a large collection of material showing the work of the Agricultural, Entomological, Veterinary and Cotton Sections. There was also a very fine exhibit from Colo East.

The largest section was that of the Agricultural Division, which also included mycological work. One feature was a series of exhibits showing the use of lime, artificial, green and compost manures upon Fijian soils, whilst there was also a fine exhibit of rice.

Perhaps the most important portion was the banana section showing the control of the Banana Borer and also the susceptibility and resistence of the various varieties to leaf spotting diseases. Virus diseases were demonstrated by means of Bunchy Top of bananas and Mosaic of sugar-cane.

An important feature was the collection of weeds, the number of which is unfortunately likely to increase.

ENTOMOLOGICAL DIVISION.

One of the most interesting exhibits of this section was a case showing a number of insects which had, in recent years, been introduced by the Department of Agriculture, with the object of controlling certain other insects and noxious weeds. In this work Fiji has been remarkably successful. The control of Levuana by *Ptychomyia*, of the scale *Aspidiotus destructor* by *Cryptolemus*, and more recently the control of *Promecotheca* by *Pleurotropes parvulus* have been phenomenal, whilst the success being attained in the reduction of the weed *Clidemia hirta* by the aid of the thrips, *Liothrips urichi*, is almost as striking.

Another interesting case was one showing a family of the butterfly *Hypolimnas bolina* which, in certain local strains, produces only females, and such entirely female families have been bred through for seven successive generations without a single male appearing. The species is also remarkable in Fiji for the wide range of variation present in the females.

VETERINARY DIVISION.

The Veterinary Division displayed a collection of pathological specimens obtained from diseased animals in Fiji and there was also displayed a large collection of dried fodder grasses present in this country. On the wall were graphs showing the progress of the work of tuberculosis eradication in the dairies supplying Suva with milk; a work which is now showing most useful results.

There were also several diagramatic representations showing the life history of some of the common parasites attacking domestic animals.

COTTON SECTION.

In the Cotton Section the new hybrid Sea Island–New Guinea Cross was shown, and also a nice display of cured tobacco, and cigars manufactured therefrom. Both these industries offer considerable promise in the future in this country.

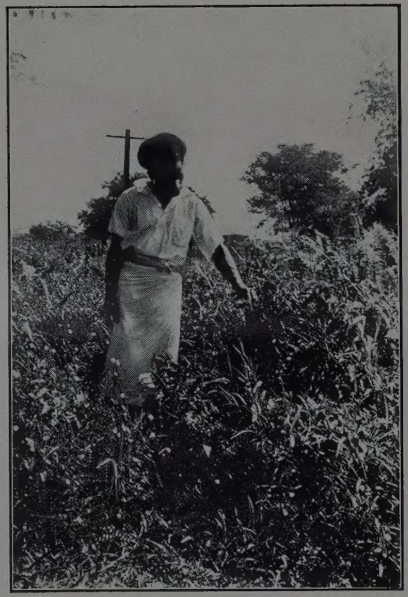
DISTRICT SHOWS.

In addition, small shows have been held in the Sigatoka district in which one of the features have been ploughing matches.

A ploughing match for horse teams owned by Fijians attached to the Vuliteitei was held at Balenabelo on the 24th of September. There were 24 competitors, and the standard of ploughing was very good. In addition, there were races and a prize for the best dog.

Solid curse below Suva old hospital, February, 1933. Recently heavily attacked by the thrips.

The same five months later, July, 1933. Note the weed all overgrown and almost disappearing.



The same one year later, July, 1934. The weed almost entirely replaced by mimosa, fern and para grass.

Photographs by H. W. Simmonds.

A bullock ploughing match was held on the 28th of September at Bemana, at which over 300 Fijians were present. There were 36 entries and the standard was also good.

Competitions were also held for cotton-picking, the best pair of bullocks, and a Victoria Cross race on horseback.

COLO EAST EXHIBIT.

The Colo East Provincial Exhibit was awarded the first prize for the best provincial agricultural and industrial exhibit. It consisted of native food crops such as yams, bananas, ndalo, kumalas, tapioca and arrowroot. Bananas were particularly striking, and the exhibit included a plant of the Sawaqa type, the indigenous banana of this country. The arrowroot was also of particular interest.

In addition to the native food crops some nice examples of native cured tobacco were shown, and home industries were represented by baskets, mats and coir rope.

BIOLOGICAL CONTROL OF NOXIOUS WEEDS, WITH SPECIAL REFERENCE TO THE PLANTS CLIDEMIA HIRTA (THE CURSE) AND STACHYTARPHETA JAMAICENSIS (BLUE RAT TAIL).

By H. W. Simmonds, F.R.E.S., Government Entomologist. E.K.S.

PREFACE.

In the following pages I propose to summarise the position regarding certain weeds in Fiji, with special reference to the control of the "curse" *Clidemia hirta* by the thrips *Liothrips urichi* and also to enclose a special account prepared by the Coconut Entomologist, Mr. R. W. Paine, of the position on the Island of Taveuni, where he has made an intensive study of the fluctuations taking place during the past twelve months.

At the end I propose to discuss the prospects of reducing the numbers of certain other major weeds by similar methods.

INTRODUCTION.

Weeds, which I have elsewhere described as "any unwanted plant, which, by its growth, interferes with the crop which it is desired shall occupy a piece of ground," are one of the major problems with which the agriculturalist has to contend. Against some weeds the ordinary cultural methods of agriculture may prove sufficiently efficient, but other weeds, owing to the possession of poisonous or other protective properties, or a deep rooting system, or by the production and rapid dispersal of vast quantities of seeds, are exceedingly difficult to combat and may justly be called "noxious."

The control of these by manual or chemical agencies frequently entails heavy charges against an estate, whilst their eradication by the peasant farmer is doubtfully economic, taking time which could be more profitably occupied were they absent.

Many of the worst of these weeds are exotic importations, some of which cause little or no trouble in their original habitat and this fact has suggested that they are there held in check by certain natural (generally insect) agencies and could these be introduced into the plant's new home it would quickly cease to give trouble.

The problem is, however, not quite so simple. Many weeds are closely related to economic crops and any agency which was destructive to such would almost certainly prove disastrous to the related crop. Again it is

probable that certain plants will be found to have a wider climatic tolerance than some of the insects which attack them and *vice versa*. Thus, in introducing the thrips, *Liothrips urichi* into Fiji, it was found that in the pupal stage it could stand a temperature of 28 degrees F. for 14 days and survive. It is certain that its host plant could not withstand this and probable that few of its own natural enemies would survive the experience. Up to the present few attempts have been made to control weeds by insect agency as compared to those efforts which have been made against insects and as yet it is probable that only two striking successes have been achieved. The first of these, the control of Prickly Pear in Australia by the Pyralid moth *Cactoblastes*, has been most spectacular, whilst in Fiji the success now being obtained in the control of *Clidemia hirta* gives promise of being comparable to the Australian achievement.

There is, however, one striking difference between the two results, in that, whereas the Prickly Pear is directly killed by the attacks of *Cactoblastes* larvæ, in the case of the Fijian *Clidemia* the action of the thrips is so to inhibit the growth of the weed as to allow competing vegetation to overgrow it and eventually kill it. It thus follows that the efficiency of the insect is largely dependent upon the nature of the soil and the vegetation it supports and the absence of such agencies as cattle which in turn destroy the competing vegetables, until such have done their work.

CLIDEMIA HIRTA AND THE EFFECT OF THE THRIPS, LIOTHRIPS AS AT 30/9/34.

I have already fully recorded* what is known regarding the introduction of this Melastomaceous plant into Fiji, the factors which led to its rapid spread and the work which led up to the introduction of the thrips *Liothrips urichi* into Fiji from Trinidad. The plant is a weed on all classes of land, but flourishes best in the damper portions of the Group, being present on Vitilevu, Vanualevu, Ovalau, Beqa, Kadavu, Taveuni, Vanuabalavu and one or two other islands. It is protected by fine hairs over both stems and leaves and cattle will not eat it. It produces large numbers of small berries filled with quantities of minute seeds, which are rapidly spread by mynahs and other birds. Starting from fences and trees and bushes it forms a dense matted growth up to six feet in height through which cattle are only able to keep open narrow tracks and is, undoubtedly, the most serious factor against which the grazier has to contend.

Although growing in such luxurience in Fiji it is not without local insect enemies, which include an Aphis, a Lecanium scale, a mite, a mealy bug, also certain fungi and a nematode attacking the roots, but, as a general rule, the effect of these is negligible. In 1929–30 as has been previously fully reported,* the writer brought from Trinidad the thrips, *Liothrips urichi*, and it is no exaggeration to say that the successful introduction of this insect has in four years, over large areas, completely changed the appearance of the landscape.

METHOD OF ATTACK.

Liothrips urichi sucks the juices from the terminal shoots and young leaves causing these to turn yellow, wilt and die back, whilst, to a certain extent, it also attacks the young berries, causing them to fall off.

The result of the wilting of the terminal shoots has been to enable competing vegetation to gain the ascendency and, where such plants as *Mimosa pudica, Mikania scandens*, Para grass and other climbing and semi-climbing plants occur, these rapidly over-run the stunted weed, causing heavy defoliation and frequent death. In the short period of four years the vegetation

* *Agric. Journal*, Fiji, Vol. 3, No. 2, "Mission to Trinidad" by H. W. Simmonds.

on several areas near Suva, has, without manual labour, been changed from a dense growth of " curse " to useful feeding grasses, whilst in many other areas, notably at Lami paddock and at the sixth mile on Princes Road similar changes are rapidly taking place.

The action of the insect is much assisted by cutting down the old high masses of the weed, when the thrips so heavily attacks the new succulent growth as to lead, as a rule, to its entire replacement with useful vegetation. As the effect of the thrips attack is dependent upon the competition of other vegetation it follows that where grazing is heavy, useful competing vegetation will have little chance to overgrow the weed and this will then continue to grow, although at a much slower rate. At the Tailevu dairy settlement, settlers inform me that whereas formerly they had to cut this weed every six months such cutting now is only required about once in two years and then only where grazing has been heavy.

DETAILS OF SURVEYS JULY–SEPTEMBER, 1934.

(1) Suva Old Hospital, 8/8/34.—This area of approximately half an acre of old solid " curse " is now almost entirely replaced by the sensitive plant and by para and other useful grasses.

(2) Princes Road, 6 miles, 19/8/34.—A vast area of the weed many acres in extent is now largely dead and all overgrown with *Mikania scandens*, whilst many openings are forming and going back to grass.

(3) Princes Road, 6½ miles, 20/7/34.—A new bush track which was coming up in a solid sward of the weed was heavily attacked and is now overgrown with grasses under which the sward of " curse " can be found.

(4) Princes Road, 8 miles, 19/8/34.—A small area cut down in 1932 is now all para grass.

(5) Princes Road, 8½ miles, 19/8/34.—A large solid area of the weed, several acres in extent. This is a wet area and the insect has made only intermittant attacks. This season, which has been a wet one, has proved a bad one for the thrips and here and at several other places there has been some renewed growth.

(6) Sawani.—A paddock here on which the old " curse " clumps had gone back to hummocks of " mimosa " has been heavily stocked with cattle and this combined with the wet season has led to considerable renewed growth.

(7) Nasinu Experimental Farm, 21/8/34.—The big area situated near the citrus trees and cut down in 1931, remains clean, despite considerable grazing, whilst the old solid area beyond the rubber is now almost all dead and replaced with other growth.

(8) Vesari River, 8/7/34.—In this wet area there was distinct regrowth, following a very severe attack by the insect. Of the renewed growth, 33 to 50 per cent. showed visible thrips attack.

(9) Wainikorokoro, 21/7/34.—Also a wet district with conidtions much the same as those at the Vesari. There was, however a great improvement since my visit in December, 1932, and much of the weed had disappeared.

(10) Wainibuka, 30/7/34.—From Naduruloulou to the commencement of the Tailevu dairy settlement the weed is completely overgrown and has largely disappeared. At the settlement, owing to heavy grazing, the weed is only being held in check.

At the far end, where the land had been abandoned and was completely occupied by the weed, grazing has practically ceased and here competing growth by *Mikania* is spreading over large areas and open grass spaces are appearing.

Along the Wainibuka River, old " curse " areas were observed to be well overgrown and gave indications of being in a transition stage back to grass.

(11) Lami old Paspalum paddock, 20/8/34.—This paddock, until recently a solid mass of " curse," is now entirely overgrown with *Mikania*, Mimosa, Desmodium and grasses and large grass covered open spaces are appearing everywhere. Here and there, however, the long continued rains have led to renewed growth projecting above the hummocks of competing vegetation. Such renewed growth was, however, over 90 per cent. visibly attacked by the thrips.

(12) Moturiki, 5/9/34.—The weed was only of scant occurrence on this island. The thrips was present and the Buli was of the opinion that the weed was receding.

(13) Ovalau, 5/9/34.—Bureta Plantation.—This was one of the most striking and satisfactory results from the introduction of the thrips that I have yet seen. Only three years ago the whole area was solid " curse " five feet high and to-day this is almost entirely replaced with grass and fern, with here and there an old clump of the weed crushed and overgrown and mostly dead.

LIMITS TO VALUE OF THE THRIPS.

Smith states (text-book of Entomology, page 26) " wet weather causes heavy mortality upon thrips generally "; and there is little doubt that *Liothrips urichi* suffers from the effects of excessive rainfall, such as has been experienced during the past 18 months.* The result has been that, in the wetter districts, the insect has had a good deal to contend against and the plant has made renewed growth. This, however, only applies to the very wet areas. Even in these wet districts, however, periodical dry spells occur enabling the insect to make rapid headway and allowing other vegetation to encroach upon the weed, which even in such situations is generally speaking, losing ground.

There is another situation in which the insect has had comparatively little effect and that is under dense shade. Such shade is not particularly favourable to the plant, although with *Clidemia*, it flowers and sets a certain amount of fruit. This fruit provides seed which will spread at times beyond the limits of the forest.

It is still impossible to forecast the final result of the effect of the introduction of the thrips and it may be another ten years before a balance has been achieved. At present despite excessive rains the insect is still advancing. In bringing about the death of the weed it is destroying its own food supplies, which even now is very abundant only in the very wet districts. This must lead to a great reduction in the numbers of the insect, leading again to renewed growth of the weed. There should, therefore, theoretically be a considerable oscillation between the two factors until a balance is struck when sufficient plants remain to maintain a thrips population sufficient to suppress any undue increase in the incidence of the host plant.

NATURE OF GROWTH REPLACING THE DESTROYED WEED.

Biological control of a weed can take place in two ways, preventative or destructive.

(1) *Preventive control.*—In the case of a short lived or annual weed any agency which, by destruction of the flowers or fruits prevents seeding, will, without damage to the plant itself, automatically lead to a reduction of its numbers.

* Mr. Paine has shown, in the second portion of this paper, that this falling off in the incidence of the insect in Fiji is apparently not directly due to the rain actually killing it.

(2) *Destructive control.*—In the case of perennial weeds, many of which root freely from the nodes, the use of such an agency would be very slow in its effects and would necessitate much manual clearing, none the less it is generally speaking the soundest method. Agencies which are destructive to the plant itself may, if not sufficiently severe, only act as pruning agents and lead to increased branching and fruiting and thus defeat their objective. They are therefore attended with greater risk.

The nature of the growth which will replace the weed will, in some cases, vary according to whether the reduction of the plant is brought about by seed reduction or by plant destruction. In the case of a seed destroyer when the parent plant dies, there is simply an absence of seeds over a given area to maintain the numbers of that particular plant, which will be replaced by the average of the plant association of that district.

In the case of a perennial which has fully occupied a vast area to the almost total exclusion of other plant life, as *Clidemia hirta* did in Fiji, a different sequence is likely to take place. Large areas suddenly become available for colonisation and there is an absence of variety of local plant life to occupy the new areas, so that those plants with rapid means of dispersal will be the first ones to colonise the area, although these may afterwards be gradually replaced by other plants. In the case of *Clidemia hirta* such plants as possess climbing ability contribute largely to its death and form the first colonisation of the new area. Such plants include *Mikania scandens*, *Mimosa pudica*, para grass and *Desmodium trifolium*. It has been felt by some that the destruction of one weed only leads to its replacement by another of possibly more virulence. This is not necessarily the case. Other weeds may replace the one destroyed, but this depends upon the nature of the soil and surrounding vegetation and the new growth should eventually become the average of the surrounding vegetation less the weed destroyed.

Some details of what has actually taken place in Fiji will be of interest.

Lami paddock.—The new growth replacing *Clidemia* consists of grasses, Mimosa and Desmodium.

Lami roadside, 7 miles.—The new growth consists largely of weeds such as Blue Rat Tail and ferns.

Old hospital.—The new growth consists of para and other grasses, Mimosa and some fern.

Princes Road, 6 miles.—On the right of the track at present the vegetation is mainly *Mikania scandens*, on the left grasses.

Sawani.—The new growth is chiefly *Mimosa pudica* on right and para grass on left. Along the roadsides mixed grasses and weeds predominate.

CONCLUSION.

I am of opinion that it will be many years before the final adjustment between the thrips *Liothrips urichi* and its host plant, *Clidemia hirta*, will be reached. None the less a vast improvement has been brought about by the introduction of the thrips and it may safely be stated at the present time:

1. That the weed is no longer the dominant feature along the roadsides and grazing paddocks of the wet zone.
2. That, in grazing land, weeding costs have been reduced by 75 per cent.
3. That, over considerable areas, where grazing is not heavy, the weed is rapidly being replaced by grasses, Mimosa, &c.

4. That on newly exposed surfaces, the plant no longer comes up in a solid sward.

There are also indications regarding the future balance between the insect and its host plant that:—

1. In areas of moderate rainfall, say, up to 150 inches per annum and on good soil, the effect of the attack of the thrips in inhibiting the growth of the weed, will, in the absence of heavy grazing, so favour the competing vegetation as to lead to its replacement by useful herbage.

2. Where, however, grazing is intense, such competing vegetation has no chance to grow and the weed will continue under somewhat stunted conditions.

3. In the wetter areas (and elsewhere too) the cutting down of the weed and the exclusion of cattle will generally prove sufficient to lead to its replacement with good herbage.

4. On poor soil, under dense shade or in very dry areas the work of the insect is inhibited, in the first and last cases probably by a lack of succulence in the host plant and in the second instance by a natural objection to shade.

5. Smith (*Textbook on Entomology*, p. 28) states "wet weather causes heavy mortality upon thrips generally"; and there are indications that such is the case with *Liothrips* so that seasonal fluctuations in its numbers are likely. None the less during the past exceptionally and continuously wet sixteen months, despite renewed growth in certain places, the insect has generally, continued to make progress.

6. During periodic dry spells the insect will also invade the big areas of the weed remaining in the 150-250 inch rainfall districts in sufficient force to break these up to a considerable extent. It seems possible that the plant will eventually exist, as it does in the West Indies, commonly on the wettest areas, that elsewhere it will occur irregularly and only in small numbers, with frequent oscillations.

7. There is no doubt that the value of the insect in Fiji is, in the absence of its own special enemies, infinitely greater than it was in Trinidad and, whilst it will be many years before it is possible to evaluate its full effect, there is evidence that such may prove comparable to the combined effect of all the numerous agencies attacking the weed in that island.

OTHER MAJOR WEEDS IN FIJI.

Whilst *Clidemia hirta* has undoubtedly been the most difficult weed against which planters and graziers in Fiji have had to contend, there are a number of other plants which occupy valuable space, reduce yields, and increase plantation costs in the country. Of these, *Lantana camara* and *L. crocea*, *Psidium guyava*, *Stachytarpheta jamaicensis* and *Solanum torvum* are the most serious.

Lantana camara and *L. crocea*.—Lantana was one of the earliest weeds in Fiji to cause anxiety, being rapidly spread by mynahs and forming dense thickets, especially in the coconut estates. Efforts to bring it under biological control had already been made in Hawaii, where Koebele* had successfully established a number of insects which attacked it.

* The introduction into Hawaii of insects that attack lantana by R. C. L. Perkins and O. H. Swezey, *Bull.* No. 16, Hawaiian Sugar Planters' Association.

Through the courtesy of the Hawaiian Sugar Planters' Association several of these were successfully established in Fiji and I am of opinion that the spread of the weed has been materially reduced in consequence. This opinion is based on the absence from Fiji of the dense thickets of the plant which I have observed in certain other countries enjoying a similar climate.

The introductions consisted of four insects. An agromyzid fly, *Agromyza lantanæ* now fully established and numerous, which destroys a considerable proportion of the seeds.

Thecla agra, a Lycænid butterfly, which destroys the flower buds and which is well established, but not as abundant as could be wished.

Thecla echion, another Lycænid, which was released on Taveuni Island, but failed to establish itself.

Teleonemia lantanæ, a Tingid, which causes browning and defoliation of the plant, but, which, whilst fully established, has proved to be susceptible to wet conditions and only valuable during dry spells.

The weed is a rare plant in Trinidad and other seed destroying agencies may exist on that island.

Psidium guyava (Guava).—With the successful control of *Clidemia hirta* this plant probably assumes the position of being the most serious weed from the planters' point of view, present in this country. Hardwooded, growing from every little broken rootlet and producing a fruit relished by man and beast, who thus spread it, its control is a most serious problem.

It also constitutes a menace to the citrus industry in that its fruits act as the main reservoir in which the local fruit flies breed and thence, in the season spread to other fruits. Near the towns its wood provides excellent firewood, this being probably the best that can be said for it in Fiji. The plant thrives in both the wet and drier portions of the Colony and at the moment little prospect can be advanced for its biological control.

In many parts of the Colony it forms a dense scrub land and I am of the opinion that there are distinct possibilities of utilising much of this guava scrub by planting mahogany, the large leaf form *Swietiana macrophylla*. This tree grows quickly, gives a dense shade and forms heavy surface roots. There is a world market for its timber and the cost of planting and upkeep would be trifling.

Guava is chiefly spread by cattle and graziers could check its further spread to a large extent by passing cattle through a quarantine yard for 40 hours, when moving same from affected to clean country.

Solanum torvum.—This weed is circumtropical in its distribution and is nowhere, so far as is known, seriously checked by insect agency. Its close relationship to cultivated crops such as tomato, bringal, potato, tobacco, Cape Gooseberry, &c., render biological methods unsafe, even if such were known to exist.

It is chiefly a weed of river valleys and good lands and hand clearing is the only practicable means of dealing with it. The plant should, if possible, be pulled out but, where too large for this method, I suggest cutting and painting with arsenic.

Stachytarpheta jamaicensis (Blue Rat Tail).—This plant, like each of the other noxious weeds here discussed, is a native of Central and South America. It is a major weed of the poorer grazing lands and counts have shown that its incidence varies from about 10 per cent. to about 25 per cent. of the total surface cover in such areas. It is also found on cultivated lands, in which, however, it is not of the same economic seriousness.

The plant is deep rooted and very free seeding and is thus not only able to withstand a certain amount of drought better than many fodder plants, but in land subject to dry spells, which is liable to have bare patches exposed, its large quantities of hard seeds enable it rapidly to colonise such newly exposed surfaces.

The plant itself is short lived or an annual, so that any agency which destroyed a portion of its seed would quickly lead to a considerable reduction in its numbers. In Fiji it is subject to the attacks of a thrips, *Haplothrips gowdeyi*, which however exercises no pressure and also to the scale *Diaspis pentagona*. This latter generally proves fatal, but seldom attacks young plants.

In Trinidad the writer found that a considerable quantity of the seeds were destroyed by a *Cecidomyiid* despite the fact that it was itself subject to a 90 per cent. or more parasitism.

At the request of this Department an investigation of this insect was made by a student of the Imperial College of Tropical Agriculture who found that two species of *Cecidomyiid* were present, but failed to breed them through in captivity.

The weed is a major pest in Fiji, Samoa, Tonga, and parts of the Solomon Islands and its reduction by biological methods would greatly benefit pastoralists.

THE CONTROL OF KOSTER'S CURSE (CLIDEMIA HIRTA) ON TAVEUNI.

By R. W. Paine, Entomologist, Coconut Committee.

E.K.E.

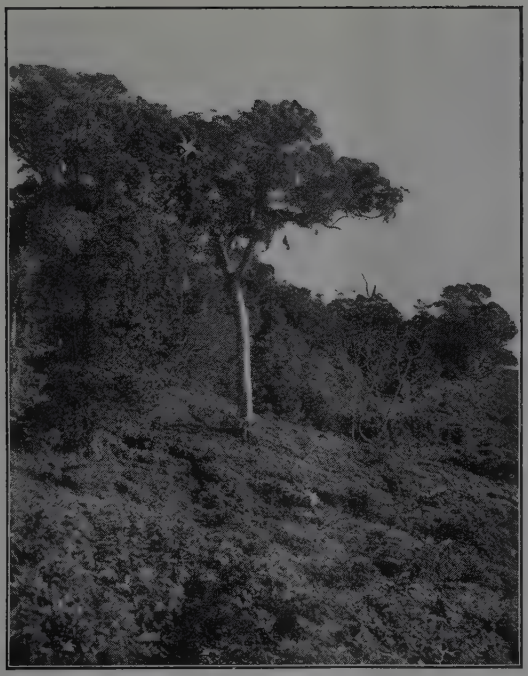
1—INTRODUCTORY NOTE.

Although the colonisation in Fiji of *Clidemia hirta*, the weed popularly known as "Koster's Curse"' has been a matter of grave concern in the main for the dairy farmer, its spread through coconut plantations, where at its worst it forms a dense scrub in which the nuts cannot be found, has brought about much loss to the copra planter as well.

In no part of Fiji are conditions so suitable for a study of the effects of "Koster's Curse"' in coconut plantations as on Taveuni. For this reason the writer of this article, who had made no previous study of this weed, or its control, was prompted to take advantage of a year's continuous residence on this island by making monthly observations of the status of the weed and its imported parasite at a few suitable and conveniently situated localities.

The study of *Clidemia hirta* in Fiji has been carried out for the most part by the Government Entomologist, Mr. H. W. Simmonds, and the writer feels that it is somewhat presumptive on his part to step into work which has been conducted with thoroughness by another local investigator. His only excuse is that being essentially a coconut entomologist he has opportunity for more frequent observations on *Clidemia* in coconut plantations than is presented to the Government Entomologist resident for the most part on Vitilevu.

With the exception of a few brief notes of a general character made in 1931 and 1932, reference to which is made in the following historical note, the substance of the present article is derived from the monthly observations which began in July, 1933, and were continued, with a few unavoidable gaps, until July of the present year.



A—"Koster's Curse" at the edge of the forest above the planted area of Ura Estate. With the exception of a few bushes of guava, one of which can be seen in the foreground, all the shorter vegetation in the photograph is "Koster's Curse."

Observations at Ura were made in this place.

B—"Koster's Curse" in Plot A at Salialevu. The photograph was taken in July, 1933, and twelve months later there was no visible difference in the size and condition of the bushes. The man's height is 70 inches.

Photographs by R. W. Paine.

2—HISTORICAL NOTE.

Clidemia is said to have reached Taveuni with coffee seed landed at St. Heliers in the north-east part of the island. The exact date of its arrival has not been ascertained, but, having spread presumably through the forest along the east coast, it was first seen in the southern part of the island by Mr. F. H. Warren, manager of Ura Estate, in 1916. On the occasion of its first discovery the writer was informed by Mr. Warren that he pulled up the only plant he saw and had its identity as " Koster's Curse " verified by Mr. E. Duncan.

Shortly after its arrival on Taveuni it was found to have spread all over the island. Its rapid spread was undoubtedly due to the fact that forest birds (especially pigeons) feed on the berries and that the forest on Taveuni, unlike that on any other sizeable island of Fiji, descends low down on the western as well as on the eastern side.

Prior to 1920 the area of land which lies across the watershed between Vuna and Salialevu was covered with *Paspalum* grass and provided good pasturage for cattle. By 1922, only seven years after it was first discovered in this locality, *Clidemia* had spread over the hills and taken possession of a tract of land which must approximate to 3,000 acres in extent. Overspreading the grass and encroaching on the outlying parts of the coconut estates Salialevu, Vuna and Ura " Koster's Curse " held uninterrupted and unchallenged command of the land until the liberation of the Trinidad thrips (*Liothrips urichi*) in April, 1930, at Salialevu and Ura.

In July, 1931, the writer walked for the first time from Vuna to Salialevu, and after passing the small Indian settlement in the locality known as Qarawalu entered the watershed area where the road ran through a dense forest of guava. On emerging from the guava near the western edge of the watershed it was startling to gaze upon the spectacle of miles of " Koster's Curse " such as the writer had never seen in any other part of Fiji, not even on the east coast of Vitilevu. Several unforrested hills, which rise to a height of 1,300 feet and skirt the road in this locality, presented uniform green flanks and crest, the colouring of which at a distance might have been attributed to the most verdant pasturage, but which on approach revealed itself as a dense, uninterrupted growth of *Clidemia*.

On close inspection the foliage of the bushes all looked green and healthy, nor were any thrips found on the shoots examined beside the road. That the thrips had established itself in this area from the colonies liberated during the previous year and was already fairly widely distributed cannot be doubted in view of its rapid increase and sudden appearance over a large tract of land at the end of 1931. But it is important to emphasise two facts: firstly, that the thrips was liberated here in April, 1930; and secondly, that its presence could not readily be detected at the end of the subsequent fifteen months.*

As the writer's observations were carried out for the most part in this southern part of Taveuni it is necessary to mention the main climatic features which prevail there. Lying immediately to the south of the high axial range, the summits of which reach up to 4,000 feet, the highest part of the southern undulating " flat " receives heavy rains from winds which blow from almost all points of the compass. The annual rainfall at Qarawalu must measure some 300 inches and it is unquestionably one of the wettest places in Fiji below an altitude of 1,000 feet. On Vitilevu it is evident that *Clidemia*

* In March, 1931, R. A. Lever recorded that the thrips was not seen on Ura. He did not, I think, visit Salialevu (*F.A.J.* 4, No. 2, p. 79).

is a serious weed only in the eastern half, or wet zone of that island, so that here in the southern part of Taveuni are climatic conditions extremely favourable to its growth. It is important to bear this in mind when considering that *Clidemia* is still the dominant plant over this tract of country in spite of the abundant damage done to it by the thrips.

In January, 1932—only six months after the first visit when no thrips could be seen—the writer revisited Salialevu and was greatly impressed by the altered appearance of the countryside. The change could be noticed even from a considerable distance, because the weed covered hills had changed from green to brown and the *Clidemia* bushes everywhere exhibited a parched appearance due to the extensive withering of the surface foliage as the result of thrips damage. So spectacular was the work of the thrips at that time and so rapid had been the destruction of the weed that one could not but form the opinion that after a few more years the land might be completely reclaimed by this insect without the intervention of further human aid. It is somewhat disappointing that such has not proved to be the case.

During the wet season of 1932 the *Clidemia* achieved renewed growth and for the last two years has remained in very much the same condition, viz., not quite so dense as it was in 1930, but of distinctly more robust appearance than at the end of 1931.

On returning to Taveuni in 1933 the reports concerning the activities of the thrips were of a very diverse nature. On estates in the north end of the island coconut planters could not say enough in favour of the thrips. On Nagasau Estate systematic weeding at some considerable cost had to be carried out until the end of 1932 in order to keep " Koster's Curse " within reasonable control. Since then no weeding has been necessary, the thrips having kept it well under control within the planted area.

From some estates in the southern part of the island the activities of the thrips were reported on without such enthusiasm. With a boundary of dense *Clidemia* above their estates—little reduced by thrips in three years—the managers of Ura and Salialevu were apprehensive of the further spread of the weed within the planted area. It was certainly quite obvious from their statements that any hopes of complete destruction of the weed, which may have been entertained early in 1932, had not been realised. From the central part of the island planters' opinions as to whether the thrips would control the weed without further cost were somewhat divided, but all were agreed that within at least the lower parts of their estates the thrips had produced a great improvement.

Now that the thrips have had time not only to colonise all the territory on Taveuni occupied by *Clidemia*, but to assume a condition of balanced population, the following questions arise in connection with the future status of " Koster's Curse " as a weed in coconut plantations:—

1. Is *Clidemia* going to continue spreading inside plantations ?
2. Is the thrips going to bring about a gradual reduction in the weed with ultimate extermination in all planted areas ?
3. Is the introduction of further parasites for the control of *Clidemia* desirable ?

These three questions can, in effect, be condensed in the comprehensive inquiry: " Is *Clidemia hirta* any longer responsible for appreciable annual losses to the coconut planter ? "

Future prospects and answers to the above questions will be reviewed after setting forth such statistical data as have been compiled and which may assist in acquiring a knowledge of the present inter-relation between weed and parasite on Taveuni.

3—OBSERVATIONS DURING 1933-34.

(*a*) *Localities Studied.*

Between the lower edge of the forest and the top boundary fence of land planted under coconuts there is in almost all parts of Taveuni a strip of land which was formerly cleared and which has since been covered by a solid thicket of "Koster's Curse" (see Plate1,A). The main conditions which make this land such an ideal habitation for the weed are:—(i) exposure to sun, (ii) lack of weeding, due to depressed economic conditions and the relative unimportance of the land as compared with planted areas, (iii) the selective feeding of cattle, hundreds of which roam wild in the forest and graze at its edge on several plants which would otherwise help to smother the *Clidemia*, (iv) usually an area of heavier rainfall than the lower land near sea level.

This cleared land above coconut estates, varying in width from about 50 yards at Ura to a mile or more at Salialevu, forms a reservoir of *Clidemia* seed which is carried by birds and pigs down the hill slopes into the coconut paddocks.

It was therefore considered that a month to month inspection of this *Clidemia* ridden country should be made, as well as observations on the weed within the planted area of coconut estates.

From July, 1933, until July, 1934, observations were made at the following situations:—

(1) In the top paddock planted under coconuts in the central part of Ura Estate.
(2) In the cleared land between the top boundary fence and the edge of the forest in the centre of Ura Estate.
(3) A sample plot, measuring 50 ft. by 20 ft., in the open country above the planted area at Salialevu (Plot B).
(4) A sample plot, measuring 50 ft. by 20 ft., in one of the top planted paddocks of Salailevu (Plot A).

The two plots at Salialevu differ from each other as regards height above sea level, and what is far more important in their degree of exposure to sunlight. Plot A lies 300 feet above sea level, and in it the *Clidemia* bushes are partially shaded by coconut trees. Plot B is about 150 feet higher, and the bushes are fully exposed to the sun all day. These differences show effect in the condition of the *Clidemia* bushes themselves, which in Plot A are taller and possess a smaller number of branches than those in Plot B. In July, 1933, when the plots were first marked out, the average height of the bushes in A was about 5 feet, and the maximum about 7 feet (see Plate 1, B). Whereas in Plot B the average was 3 feet 6 inches and the maximum height 6 feet. Thus in Plot B the plants contained a greater number of surface shoots per ground stem than do those in Plot A.

(*b*) *Observational Method.*

Observations did not take the same form in each situation, but were as follows:—

In the top paddock at Ura no detailed inspection of any bushes was made, but on walking up to the boundary fence the writer counted, out of 50 small isolated plants chosen at random, the number which showed thrips damage in the new shoots. This is far from a precise method of determining the exact number of thrips, but it serves to show the relative extent to which the weed is attacked from month to month beneath the coconuts. As all the observations were made by one person their value as comparative data is reasonably significant.

Above the fence at Ura three sample branches from the dense clumps of *Clidemia* were cut each month. The samples varied slightly in " branchiness " according to the exact position in which each one grew, and to slight differences in the width of the stem; but the samples cut each month were chosen so as to correspond with each other as far as possible in average size and branchiness. The mean diameter of the stem where cut varied from 5/16 in. to $\frac{8}{8}$ in., but the majority of stems were $\frac{1}{2}$ in. thick. Care was taken in extracting the samples from the parent bushes not to tear off the terminal shoots or fruits. The number of ripe and green berries on each sample was recorded and the new shoots were picked off and carefully examined for thrips. The number of shoots with and without living thrips (eggs not being taken into account) was then noted. In order to reduce the margin of observational error as far as possible a " new shoot " was considered as the terminal part of a branch, the youngest leaves on which measured less than two inches in length. This definition was rigidly adhered to and is important to bear in mind when we compare the observations made at Ura with those made at Salialevu.

Finally, general observations on the appearance of the bushes and the abundance of *Mikania scandens* (" Mile-a-minute ") and Dodder were made.

At Salialevu the two plots were both treated in the same manner. The general conditions of the plants and the abundance of *Mikania* and Dodder was noted. In addition, 40 terminal shoots (20 from each end of the plot), showing no signs of thrips damage, were picked from each plot and the number was recorded on which living thrips (excluding eggs) were found. The percentage of shoots on which living thrips were found was almost always higher at Salialevu than at Ura. This is because at Ura the shoots with newest leaves less than two inches in length included those from the more shaded, underlying parts of bushes where thrips are seldom found, and also those which have previously been so badly damaged by thrips that the latter had already forsaken them.

At Salialevu, on the other hand, the shoots examined were all picked from the surface, well-illuminated foliage, that is, from that part of the bushes where thrips occur in greatest abundance. Moreover, the fact that they showed no visible signs of thrips damage indicated that these shoots were all sufficiently succulent still to be frequented by living thrips.

The percentage figures given for thrips infestation gives no measure of the contemporaneous percentage of surface shoots with thrips damage. On Salialevu Estate " Koster's Curse " is growing in a fairly solid thicket, over much of the higher planted area, of which Plot A is a very fair sample, and the importance of this weed as a pest on a coconut estate can hardly be greater than in this locality. For this reason I chose Salialevu as a place in which to make observations in addition to those made in the more accessible site at Ura.

(*c*) *The Data Obtained.*

Observations were made at Ura at the beginning of each month, except in the month of November, and at Salialevu in the middle of the month, except for the months of April and May, on account of absence from the island, sickness and rains respectively.

Table I shows the figures recorded at Ura. Column 1 in the table shows the extent to which the thrips attacks " Koster's Curse " in the higher parts of the estate. It will be noted that on only one occasion were less than 50 per cent. of the bushes without evident damage by thrips. Thrips damage was seen in an average of 70 per cent. of the bushes throughout the year and

in October, 1933, no bush lacked signs of previous thrips attack. These figures show clearly that in the partially shaded ground in a coconut plantation the thrips is permanently widespread and efficient. None of the bushes had grown to a height of more than three feet. Although figures cannot be supplied to substantiate this statement it would appear that the nearer the weed is growing to sea level the more extensive and severe is the damage caused to it by thrips.

The second column shows the average number of new shoots (*i.e.*, those with youngest leaves of less than two inches in length) in the sample branches cut each month from the bushes above the nuts. It is necessary to give these figures because in studying the relative amount of fruit from month to month it must be remembered that the greater the number of lateral branches (*i.e.*, potential new shoots) the greater the number of fruits. The figures for fruiting are shown in columns 5, 6, 7 and 8. For a comparative study of fruiting from month to month reference should be made to the figures which are given in column 8. These allow for variation in the average number of branches of the samples examined each month.

Column 4 of the table shows the relative extent to which the plants were infested with thrips each month. Although the percentage of thrips-infested shoots varied from 35, in October, 1933, to 12, in July, 1934, the extent to which the surface foliage was browned with thrips damaged leaves appeared to vary very little from month to month, and, if slightly damaged (*i.e.*, yellowish) leaves be taken into account it could be roughly stated as about 50 per cent. during the entire period. The predominant colour of the bushes was always green in contrast to that noted at Salialevu early in 1932. It was noticed that in September many of the younger leaves showed a large amount of bleaching, although no signs of thrips damage on many such leaves could be detected. It is probable that the plants were showing the effects of partial devitilisation from thrips damage in a reduced production of chlorophyll. This, as would be expected, was observed only towards the end of the cool season when the growth of most plants in Fiji is considerably retarded.

The climbing plants *Mikania* and Dodder were fairly abundant throughout the year and whenever a sample stem of *Clidemia* was cut it was always necessary to sever several stems of *Mikania* in order to free it from the main bush. Very little difference in the condition of the bushes could be observed compared with their condition a year earlier, but a good many more than 50 per cent. of the terminal leaves on the sunlit surface of the bushes showed yellowing from thrips damage.

In Table II the figures obtained at Salialevu are shown. It can be seen that in so far as thrips infestation is concerned there is a close similarity between the two sample plots. If anything there was a greater abundance of thrips in the lower lying Plot A. On analogy with other places one would expect the thrips to occur more extensively in the less shaded Plot B than in Plot A beneath coconuts, and the fact that it does not do so lends support to the theory enunciated above, that the intensity of thrips infestation increases the nearer the host plant grows to sea level.

The average thrips infestation for the whole year in both plots was 58 per cent. This means that more than half the new shoots put out by the plant were continuously damaged by thrips. The extent of the damage varied with the relationship between thrips population and food supply. When most of the new shoots contained thrips the damage done to each shoot was severe enough to cause the tip leaves and stem to wither completely. When

the thrips infestation was less severe, the damaged leaves tended to curl slightly but continued to grow. In the coconuts (Plot A) the infestation only once fell below 40 per cent. which shows the extent to which the bushes were attacked within the planted part of this estate.

The fruiting of *Clidemia* at Salialevu was not studied in detail as at Ura, but ripe berries are so conspicuous as to render their relative abundance from month to month readily comparable. There appears to be a definite season of heavy fruiting from July to September. This is also the season of higher thrips infestation so that if the thrips causes any appreciable diminution in fruiting it is likely to take effect late in the year.

The figures given in Tables I and II for thrips infestation are shown graphically in Fig. 1.* The curves plotted in Fig. 1,A show the average infestation in both places at Salialevu compared with that above the fence at Ura and of the bushes in the top planted paddock at Ura.

Although the figures given are percentages and it is thus possible to plot them together in one graph it is to be remembered that they are not strictly comparable; because in each place, as has already been pointed out, the data were obtained in a different manner. A curve which represents the average of the three given in Fig. 1, A, however, shows that the general level of thrips abundance increases from July to October after which there is a steady decrease till the end of the year, and then a maintenance of level through the early part of the year. This average curve is shown in Fig. 3, together with the curve for rainfall measured at Ura house during the period concerned. It will be seen that there is a tendency for the thrips infestation to decrease when the rain increases, and *vice versa*. This is not due to a destruction of the thrips themselves by the rain because in January and June observations made immediately after torrential rains showed thrips individuals of all stages to be more abundant than in the preceding month. It is due to an increased growth in the host plant with a consequent relative decrease in the density of thrips population. The rainfall curve for the whole period is not quite typical because less than the usual amount of rain fell during the first four months of 1934, whereas the rainfall in May was exceptionally heavy. There is a considerable difference in the amount of rain falling at Ura house and that falling higher up the hill and at Salialevu where the *Clidemia* observations were made, but the relative variation in rainfall from month to month is probably fairly similar in all these places.

In Fig. 1, B, the data obtained from Plots A and B are compared in graphical form. It will be seen that the relative abundance of thrips from month to month corresponds fairly closely in the two plots. This is what one would expect and shows that the method of measurement is satisfactory. The most marked divergence between the two plots is shown in September, 1933. But this can readily be accounted for. In Plot A there was a die-back of the tips of the bushes after August amounting to some two inches. This meant that all the young succulent leaves, on which the thrips feed for choice, fell off and many thrips either departed to other places or perished. In Plot B where the plants are more bushy the maximum amount of thrips infestation did not occur until a month later than in A. When it did occur, in September, only three terminal shoots without signs of thrips damage could be found in the whole plot. These, of course, were heavily infested with thrips.

* Graphs not printed.

In all the graphs for Salialevu, the intermediate positions for April and May, 1934, when no observations were made, are shown by plotting a steady rise or fall between the points given for March and June. The intermediate points thus shown are hardly likely to be very accurate but it seemed better to make each curve continuous rather than to leave it broken.

In July, 1933, the general appearance of the *Clidemia* bushes all over the Salialevu–Qarawalu area was green or yellowish-green and they remained thus all through the following year. Never once did they appear brown as was the case early in 1932.

The greatest amount of thrips damage was noticed in October. At that time 25 per cent. of the shoots had no terminal leaves of less than two inches in length. There was very little fruit on the bushes. The green berries present in September having fallen off as well as the ripe ones. Perhaps this is a definite instance where severe damage by thrips produced an immature fruit-fall.

The fruiting of " Koster's Curse " at Ura and Salialevu is shown in the graphs given in Fig. 2. Fig. 2, A, shows a comparison in the fruiting between Plots A and B at Salialevu. The period of maximum fruit formation is here seen to occur from July to September, while there is an intermediate period of fruiting at the beginning of the year. Although the curves for the two plots at Salialevu correspond fairly closely a comparison between these and the curves in Fig. 2, B, for Ura indicate that there is no clearly defined season of maximum fruit production in different localities. The only noticeable similarity in all the curves is a sharp decline towards the end of the year followed by a sharp rise in January and February. The output of fruit is more likely to be influenced by variations in the rainfall. Thus at Ura it will be noticed that the rain curve (Fig. 3, broken line) anticipates the fruiting curves in Fig. 2, B, by a month almost all along its course. After a heavy rainfall in one month the ripe fruits increase the next . The relationship thus exposed seems too consistent to be due to coincidence.

If this is so the difference in the occurrence of ripe fruit at Ura and Salialevu might well be accounted for by local variations in the rainfall which must be fairly considerable.

4—THE PRESENT STATUS OF CLIDEMIA ON TAVEUNI.

We have already discussed the arrival and early spread of " Koster's Curse " on Taveuni: how it took possession of a large area of grass-covered land in the south of the island and how it has gradually invaded coconut estates from the cleared, unplanted land along the lower edge of the forest. In the last section such figures are presented as have been obtained during the past year to show the progress of the weed's growth and its control by the imported parasite *Liothrips urichi*. It remains to discuss the present status of the weed as a threat to the well-being of coconut estates; and then in a final section, to see what further steps it may be desirable to take in order to remedy the ill which may still result from its presence on coconut estates.

It is evident to every coconut planter on Taveuni that where " Koster's Curse " has invaded the lower parts of a plantation it is now no longer necessary to weed it there. This does not, however, always apply to the higher paddocks, especially at the south end of the island, while those which are planted under coconuts are important to keep clean.

At the time of writing (September, 1934) when the relative abundance of thrips and *Clidemia* is very much the same as it was last year there is not a

coconut planter on the island who can say that he has derived no benefit from the importation of the thrips. But it is now quite evident that the complete reclamation of land in which *Clidemia* has been allowed to form a solid thicket six or more feet in height is not to be expected without further expenditure on the part of the planter.

The figures given in the previous section indicate clearly that in the higher lands, in which is included Plot A of Salialevu, fruiting is still taking place during most months of the year and in these places the bushes of *Clidemia* are over three feet high. For about the first two hundred feet above sea level, up to which height are included the most valuable coconut lands on the island, no *Clidemia* bushes of more than three feet in height have been seen, and although small bushes are in some cases quite numerous they bear little or no fruit owing to the severity with which they are attacked by the thrips.

It is also quite evident from the figures that the thrips is always present in at least fair abundance even in the wettest localities and after the heaviest downpours. In this respect it differs in a most satisfactory manner from the imported *Lantana* bug *Teleonemia* which becomes very scarce in the wet season. Planters are apt to judge thrips abundance by the extent to which the tip leaves of the weed are discoloured as a result of thrips feeding. But it is to be remembered that once the new leaves show any large amount of discolouration at the base the thrips will forsake them and usually the numbers of thrips are greatest in bushes where the new leaves are relatively green. The reason why the new leaves of bushes do not always show thrips damage is that one lot of new leaves falls off while the tips of the stems wither after severe thrips attack and then a new lot of leaves opens up and remains green until the thrips has had time to spread on to them and feed for a week or ten days.

It is not certain from the information obtained that there is a definite fruiting season applicable to all localities. This year the largest output of fruit at Salialevu was in July and August, whereas at Ura most berries ripened in January and February. It would be necessary to carry observations over several years before any definite conclusions could be reached.

There is no direct evidence that thrips attack prevents or reduces fruiting in the higher areas; but, as is pointed out above, in the land lying near sea level the bushes never bear much fruit.

The present manager of Salialevu Estate told me that before the thrips began to operate in that locality it was impossible to ride through the top paddocks without clothes becoming stained with the purple juice from the ripe berries. For the last three years he has not experienced this inconvenience.

To sum up it may be said that the growth of "Koster's Curse" inside coconut estates on Taveuni is no longer sufficiently extensive to cause serious inconvenience by preventing the discovery of nuts on the ground, except at Salialevu.

5—FURTHER MEASURES OF CONTROL.

It has been stated that "Koster's Curse" is still causing a considerable loss of nuts at Salialevu. It is also still in possession of a large tract of potential grazing land between there and Vuna. Furthermore, a few planters in other places are still of the opinion that it is spreading and that its control will require the application of further measures than that already effected by the introduction of the thrips.

At the present market value of copra it would certainly be uneconomical to embark upon any further parasite introductions, even if there are in existence insects which could improve on the excellent work now being done by the thrips. Weeding, moreover, it too expensive to be kept up as a permanent measure. But the writer is of the opinion that there is one method of dealing with this weed, which, while in certain places involving some expense at the start, should with the aid of the thrips provide satisfactory results in the end. This method lies in the prevention of cattle gaining access to the places where the weed is thick. This suggestion is far from an original one, and may not meet the needs of every plantation; but on Nagasau Estate in the north of Taveuni the results of this experiment have been watched with interest and it has been a source of wonder that in upland country the "Koster's Curse," which in places is as dense and as high as at Salialevu, in cattle free blocks is now scarcely visible: the bushes having been smothered by *Mikania*, "Thurston Grass" (brought up there from the coast) and Para.

It is well known that *Mikania* climbs rapidly over dead wood. Even in places where cattle run there is always some of it visible in the "curse" bushes and more especially where the tips of the plants have died as a result of thrips attack; but when cattle can get at it they prevent *Mikania* and other less important plants from growing sufficiently rapidly and luxuriantly to smother the *Clidemia* after the thrips has attacked it and before it has had time to put out a new lot of surface leaves. The rainfall at the back of Nagasau Estate is comparable with, although probably not quite as high as, that at Salialevu. So that one is driven to believe that the presence of cattle in the latter and their enforced absence in certain parts of the former is the factor responsible for this otherwise unaccountable difference in the state of the "Koster's Curse" in these places.

The writer holds the opinion that the damage inflicted by the thrips at the back of Salialevu in 1931–1932 was more severe than it has been during the last two years because at that time the *Clidemia* was so thick and healthy and contained such small amounts of other plants that wild cattle, which now enter it, did not then do so. It is his belief that were cattle to be excluded from this area and from any other higher paddocks on Taveuni "Koster's Curse" could be reduced to negligible quantities. But in this, like most other things, supervision is necessary in order that the right smothering plant and the right replacement plants are present. In most places, if not all, *Mikania* will probably prove the best smotherer, and it is already present. But when the "curse" bushes have been lowered the *Mikania* will die back and unless suitable grasses are present the "Koster's Curse" will regain control, or, as has happened in a few places already, other undesirable plants will take its place.

6—SUMMARY.

Clidemia hirta arrived on Taveuni more than 20 years ago. It was first seen at Ura in 1916, and rapidly spread round the Island, invading the higher parts of coconut estates and other cleared land bordering on the forest.

It increased so rapidly, until *Liothrips urichi* was liberated on the island in 1930, that in a matter of a few years planters were obliged to weed certain parts of their estates in order to find the nuts.

By the end of 1932 the thrips was well distributed over the island and was more abundant then than it has been since. It brought about a very considerable destruction of surface foliage in the *Clidemia*, even in upland country where the weed had formed a solid thicket six or more feet in height; and it overcame the need for weeding in the lower parts of estates.

Monthly observations were made at Ura and Salialevu from July, 1933, to July, 1934, the data from which are shown in tables and figures. During these observations it became apparent that, although subject to fairly marked seasonal fluctuations a balance has been struck between weed and parasite, in which the population of the latter is maintained in at least fair abundance.

Clidemia is at present controlled by the thrips over all the lower lying parts of coconut plantations on Taveuni. But it is still a weed of serious economic importance in the higher parts of certain estates, notably Salialevu.

It is unlikely that *Clidemia* will be further reduced to uneconomic quantities without some further expenditure on the part of coconut planters. Where cattle run *Mikania scandens*, which would otherwise smother *Clidemia* after thrips attack, is kept in check. It is suggested that the most practicable method of eradicating *Clidemia* in upland country on Taveuni is by the temporary removal of cattle, so that other useful fodder plants are given a chance to replace the weed after it has been smothered by *Mikania*.

TABLE I.—CLIDEMIA AT URA.

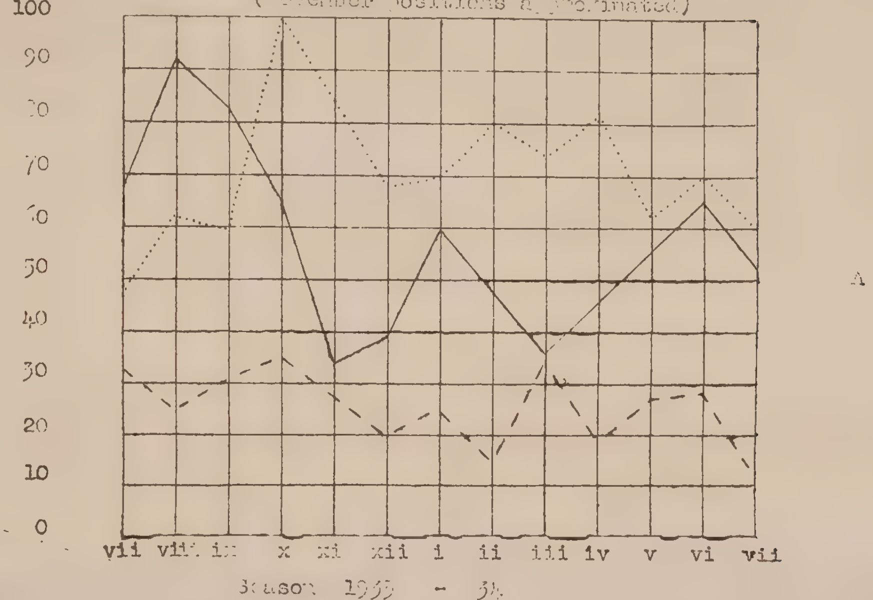
	Bushes in top planted paddock.	Bushes between top boundary fence and forest at 1,000 ft. above Sea level.						
1933–34	1 Percentage of bushes showing damage by thrips.	2 Average No. new shoots.	3 New shoots on which thrips were found.	4 Percentage of shoots on which thrips were found.	5 Average No of ripe berries.	6 Average No of green berries.	7 Percentage of berries which were ripe.	8 Ripe fruit index *
July ..	47	18	6	33	3	106	3	·17
August ..	62	24	6	25	19	171	10	·79
Sept ..	60	32	10	31	12	212	5	·38
October .	100	37	13	35	46	326	12	1·24
Nov. ..	..	..	..	..	..	..	..	..
Dec. ..	68	41	8	20	7	234	3	·17
Jan. ..	70	52	13	25	66	296	18	1·27
Feb. ..	80	53	8	15	93	391	19	1·75
March ..	74	50	17	34	25	216	10	·50
April ..	82	48	9	19	14	144	9	·29
May ..	62	26	7	27	16	162	9	·62
June ..	70	36	10	28	13	289	4	·36
July ..	60	34	4	12	16	248	6	·47
Average for year.	70	..	..	25	28	233	11	·67

* This is the number of ripe berries divided by the number of new shoots.. This is considered to express the relative amount of fruit from month to month more accurately than the plain figures for ripe fruits counted. In November. 1933 no observations were made.

Fig. 1

THE OCC[illegible] OF THRIPS (T. [illegible]) ON " [illegible] "
(Clidemia hirta) [illegible], 1933-34.

—— Average [illegible] Thrips infestation in Plots A & B at Jalialevu.
- - - - Thrips infestation of new shoots, above fence at Ura.
.... Thrips [illegible] plants in top paddock, Ura.
(November positions approximated)



Percentage of Thrips infestation of undamaged Surface shoots of Clidemia at Salialevu.

.... Plot A - - - -Plot B
(April & May positions approximated)

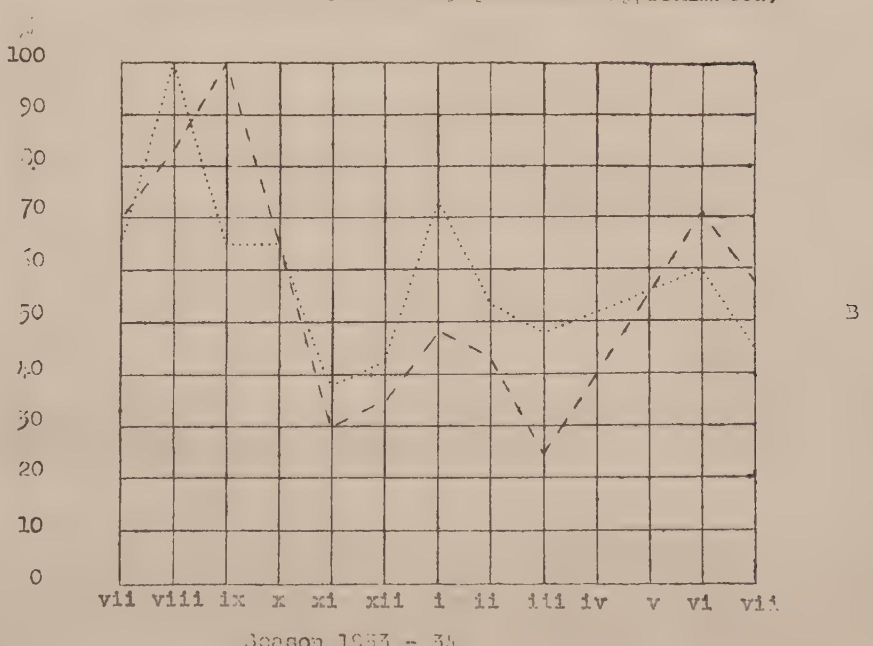


TABLE II.—CLIDEMIA AT SALIALEVU.

	Percentage of undamaged surface shoots in which living thrips were found.			Condition of ripe fruits.*	
1933–34	Plot A.	Plot B.	Average of both plots.	Plot A.	Plot B.
July ..	65	70	68	Numerous	Numerous
August ..	100	83	92	,,	,,
Sept. ..	65	100	83	,,	,,
Oct. ..	65	65	65	Very few	Few
Nov. ..	38	30	34	None	None
Dec. ..	43	35	39	,,	Few
Jan. ..	73	48	60	Few	Fair Number
Feb. ..	53	43	48	,,	,,
March ..	48	25	36	Very few	Few
April ..	..	..	..	..	..
May ..	..	..	..	..	..
June ..	60	70	65	V. Numerous	Numerous.
July ..	45	58	52	Numerous	A fair number
Average for year	59	57	58	....	....

* The entries hereunder are taken from notebook general observations. No statistical counts were made, so the data are only of relative value. In April and May, 1934, no observations were made.

TOMATO WILT OBSERVATIONS.

PART I.

By H. W. Simmonds, F.E.S., Government Entomologist.

INTRODUCTION.

Tomato wilt is, in Fiji, extremely virulent, destroying plants of all ages, but being particularly severe when such are from six to eight inches high. The writer has seen a field of eight or ten acres with something under twenty survivors only, as a result of this trouble.

The disease first shows itself by a slight wilting of the tips of one or two leaves, generally on one side only of the plant. During the following night the plant recovers, but next day, if dry, generally wilts and collapses. In wet weather it may struggle on for several days.

The disease has annually caused considerable losses in the writer's own garden, which is black soil overlying soapstone and situated in Suva.

In the 1933 season, on the assumption that the wilt was of fungoid (*Fusarium*) origin, a number of soil disinfectants were tried, such being Cheshunt Compound, Phenile and Formaldehyde, but with no marked improvement. In view, however, of the fact that the causal organism has now been shown to be a bacterium it is probable that such liquid disinfectants would only be of temporary value and re-infection of the soil would occur with the first heavy rains.

Early in 1934 certain flower-beds in this same garden were treated with sulphur in an endeavour to correct what was considered to be an alkaline condition and this resulted in a great improvement in the vigour of the plants next grown, as well as an absence of certain common root diseases. This suggested that the sulphur also acted as a soil fumigant and might be used with advantage for tomatoes.

NATURAL RESISTANCE.

In the writer's garden one or two plants have shown early symptoms of the disease and have subsequently recovered, but whether this was actual resistance is uncertain, as the causal organism had not at that time been isolated. There is also a small fruited variety of the cherry type which has run wild and, some of these appear to show resistance, frequently growing well on soil known to be heavily infected. On the other hand, only a percentage of these seedlings survive and there is considerable mortality in the early period of growth. Soil temperature appears to affect the resistance of the plants, but it is uncertain in what way, in view of the fact that it has now been shown that the causal organism is a bacterium (see Part II by B. E. V. Parham). It may arise simply from drier conditions.

Undoubtedly the ideal remedy for the disease would be to develop naturally resistant strains and it was with the objective of finding such that the first efforts were made. It was thought possible that amongst locally saved seed strains might exist which possessed a measure of resistance and that such could be improved by selection.

FIRST OBSERVATIONS.

With this objective three small areas, Plots A, B and C were selected and planted in January as follows:—

Plot A.—This plot, approximately 12 ft. by 8 ft., was normally occupied by weeds amongst which were self-sown plants of a wild cherry type of tomato. The land was cleared and planted with a tropical strain of the "peach" variety, obtained from Samoa, where it had passed through many generations. Although early growth was satisfactory all the plants wilted and died before reaching eight inches in height. In February the land was replanted with a locally saved strain of Sutton's "Best of All" which had shown some apparent resistance. This lot also all died of wilt prior to reaching ten inches in height. No further efforts were made on this plot.

Plot B.—This plot was approximately 8 ft. by 15 ft. in area. It was set out in February with the same strain of Sutton's "Best of All." After good early growth wilt set in when the plants were about ten inches high and only three, out of fourteen, survived and fruited. As these three were clustered at one end it is doubtful if their survival was due to resistance, but rather to isolation.

Plot C.—This plot was approximately 6 ft. by 12 ft. in extent. It was also set out in February, but in this case the local wild cherry type was used. Good early growth was soon followed by wilt symptoms and all plants had died before reaching ten inches in height.

There were thus three separate areas known to be heavily infected with the disease and two of these, B and C were used for subsequent observations.

SECOND SERIES OF OBSERVATIONS.

Plot B.—Early in March this plot was divided into two sections, the upper one being heavily treated with fine sulphur, at the rate of about half a pound per square yard, whilst the lower was left untreated as a check. Both portions were replanted immediately after treatment with the same strain of "Best of All," five plants being set out in each section. One plant died of wilt on the first of April in the check area, followed by two more on the 5th, and by the 11th the remaining two had died. In the treated area the first wilting occurred on the 6th when two plants went down. This was

followed by two more on the 11th, leaving only one survivor. This plant fruited, bearing a fair crop.

Plot C.—On the same date this area was similarly divided and treated, five plants of the same " Best of All " variety being placed in the treated area and four in the check. By April 6th all the check plants were dead and all in the treated area appeared healthy. Two days later however, two of these showed the disease and by the 16th all had succumbed. These results were disappointing. Undoubtedly the powdered sulphur had indicated a measure of control, as shown by the sole survivor in Plot B and the fact that all the plants in the treated portion of Plot C were healthy two days after the last one in the two check areas had died. It was thought possible that the plants had been set out too soon after the application of the powdered sulphur and it was therefore decided to replant.

THIRD SERIES OF OBSERVATIONS.

In this series the land was simply redug and no fresh sulphur added except to extend Plot B by about two feet due to the presence of the one survivor from the previous trials.

Plot B.—On the 9th May five fresh plants of the same strain of " Best of All " were set out in each portion. By June 16th none of the plants on the treated area had shown symptoms of the disease. On the untreated area, however, two had died, one was dying and one had shown symptoms and recovered, only one being healthy.

Plot C.—This plot was similarly treated on the same date, nine plants of the same variety being set out in each row. By June 16th two of the plants on the treated area had died of wilt, one of some other trouble and one was showing symptoms of the disease, but subsequently recovered. On the untreated check portion eight plants had died, only one remaining healthy. No further deaths occurred in either row and the survivors gave fair crops of rather small fruit.

CONCLUSION.

Up to this time it had been supposed that *Fusarium* wilt was being dealt with. As it has now been shown to be bacterial, it seems probable that the above measure of control was brought about by increasing the acidity of the soil and, as the drainage was from the treated to the untreated, some effect would also probably be felt in the latter. Soil samples have been handed to the Government Chemist to test the acidity in the treated and untreated portions. It may be mentioned that in Sumatra it has been shown that the bacillus causing this wilt cannot live in soils which are highly acid or highly alkaline and the present observations confirm that finding for local conditions in the black soapstone soils of the Suva district of Fiji.

Economically, the costs would prohibit the use of the method except in private gardens since sulphur costs 3d. per lb locally.

PART II.

By B. E. V. Parham, M.A., Agricultural Officer.

NOTE ON WILTS OF TOMATO.

Up to the present the wilt diseases of tomatoes have been generaly regarded as due solely to *Fusarium Lycopersici*, although no record exists of the local identification of this pathogen.*

* Since the above was written several cases of Fusarial Wilt (" Sleeping Disease ") have been observed; and the symptoms compared with those of Bacterial Wilt.

The Government Entomologist, who has studied the effect of soil treatment as a means of control, submitted some specimens of wilted plants to me for determination of the causal organism. Examinations of this material and of plants at Navuso Experimental Station have established the presence of bacterial wilt, concerning which the following notes are recorded.

SYMPTOMS AND GENERAL APPEARANCE.

The bacterial disease is characterized by the wilting of the plant usually before the flowering stage is reached and in many cases when the plant is not more than nine or twelve inches high. Frequently the first visible symptom is the wilting of a leaf or branch; this is followed by the failure of the whole plant. Stems cut across show a discolouration of the vascular bundles, and cavities caused by the collapse of parenchyma tissues. The central part or pith of the stem is nearly always involved.

In the case of Fusarial wilt, the first symptom appears in the early stunting of the plant. The disease progresses rapidly and manifests itself at blossoming time or shortly afterwards by a yellowing of the older (lower) leaves. The disease is characterized by a wilting of the tenderest foliage during the hottest part of the day, followed by recovery during the night. Finally, the wilted plant collapses, withers and dries up. The symptoms of the two diseases are therefore distinct; the bacterium causing a rapid wilting of young plants, not accompanied by distinct yellowing of the lower leaves as in the case of *Fusarium* wilt, nor in the latter disease is the pith of the stem involved except in extreme cases.

CAUSE.

In the present case it was found that the tissues of affected plants (even apparently healthy parts) were invaded by motile bacteria, which were also found in large numbers in the expressed sap.

A series of cultures was made and in every case the typical smooth, opalescent colonies described for *Bacillus solanacearum* E.F.Sm. were obtained (Smith, 1920). These colonies were made up of motile, polar flagellate bacilli; and although inoculation tests have not been undertaken, this identification is given on account of (1) the microscopic symptoms of the disease, (2) the constant isolation of the motile bacteria, and (3) the absence of fungal mycelia or spores in plant tissues and cultures. Had *Fusarium* been present evidences of this fungus would have been seen.

CONTROL.

Bacterial wilt is commonly a wound-infection disease; and infection may occur through wounds not only in the roots but also in stems and leaves caused by biting insects or other agency. Infection is frequently through broken or punctured roots and particularly in carelessly transplanted seedlings or in plants whose root systems are attacked by nematodes.

As the pathogen is capable of living in a virulent state in the soil, the possibilities of control are slight. Nothing short of steam sterilization of the soil is likely to clear the disease from affected areas, but the following points are worth attention:—

1. Sterilization or disinfection of seed bed.
2. Rotation of crops.
3. Use of resistant varieties.
4. Plant sanitation.

With regard to sterilization it is advisable to disinfect all tomato seed before sowing. Berkeley (1927) advises the use of Corrosive sublimate (Mercuric

chloride, 1/2000) for this purpose, the seed being tied in a muslin bag and submerged for ten minutes. After rinsing two or three times in clean water it is spread out to dry or planted at once.

Many tomato diseases start in the seed-bed or box. It is therefore advisable to sow the seed in clean or sterilized soil. Other than by steam, the following methods of soil sterilization are recommended:—

(*a*) *Formaldehyde* (3 pints to 40 gallons water) applied at the rate of 1 gallon of solution to 1 cubic foot of soil.

(*b*) *Cheshunt Compound.*—This may be applied to seed-beds, plant-beds and soil in which plants are growing, and will destroy disease organisms without injuring the plants. It is of great use as a check to the further spread of disease.

Rotation of crops has been found to be essential in most cases where soil organisms are concerned. In this connection at least a four to five-year rotation, excluding such plants as peppers and egg-plants which are also susceptible, is recommended.

The use of resistant varieties is to be regarded as the most satisfactory solution for the gardener. In this connection, five varieties from Queensland, reputedly resistant to *Fusarium* wilt, were grown at Navuso Experimental Station during 1933 with good results, the percentage of wilt being as follows:—

Variety.	*Loss due to wilt.*
Resistant Stone	25 per cent
Bowen Buckeye	8½ per cent.
Denisonia	4 ,,
Bowen Pride.	4 ,,
Bowen Marglobe	4 ,,

It is to be noted that the seed-beds were treated with Cheshunt Compound and the plants grown in "new" soil not known to be infected. During 1934, seed locally produced from the above varieties has given plants with apparently less resistance to wilt under similar conditions. Briant (1932) states that there is no evidence of varietal resistance to *Bacterium solanacearum*; and no varieties resistant to *Fusarium Lycopersici* have yet been determined in Trinidad.

Plant sanitation is also essential. Only strong, healthy plants should be put out, and all weak and sickly ones destroyed. All plants which show any signs of wilt should be immediately removed and destroyed, as also all plant refuse, so as to avoid carrying over the disease to the next season and crop.

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Briant, A. K. 1932—"Tomato Diseases in Trinidad," *Trop. Agric.* IX, Parts 3 & 4.
Smith, E. F., 1920—"Bacterial Diseases of Plants," London.

OBSERVATIONS ON RAT DAMAGE TO COCONUTS ON TAVEUNI.

By R. W. Paine, Entomologist, Coconut Committee.

1. Introductory.

It is common knowledge that rats do a considerable amount of damage to coconut estates in many tropical countries. In Fiji, their importance to the coconut planter has been remarked on by several investigators during the last ten years—notably by Taylor and Surridge.*

Estimates of the damage are given by Turbet as 10 per cent. (*Agric. Circ.*, 1925, Vol. 5, No. 2, p. 98), and by Taylor as 6·85 per cent. These writers record estimates by certain planters of rat damage amounting to 50 per cent. and 30 per cent. locally, but they are cautious in the acceptance of these figures.

Taylor is the first scientific investigator to have made a statistical survey of rat damage to coconuts in Fiji, and his estimate of about 7 per cent. for the whole group was compiled from data derived by counts of immature and mature coconuts on the tree, for 460 trees in twenty representative estates in Fiji.

In estimating rat damage, Taylor assumed that practically all those nuts which fall from immature fruit branches older than the fourth (counting the youngest open branch as number one), are damaged by rats. This assumption is tenable, in spite of the fact that largish, green nuts, bearing no signs of rat damage may often be found lying on the ground. The apparent abundance of these large, immature nuts is due to their not being collected by copra cutters; so that they accumulate and suggest that their fall is brought about by some relatively important and definite factor amongst those which operate to reduce the numbers of maturing fruits. Actually the fall of many such nuts is brought about by rats, although no tooth marks are to be found on the nuts themselves. But the majority fall off for a number of obscure reasons, probably largely physiological, operating through the medium of the tree itself. These are included in what Taylor refers to as "normal nutfall" (l.c., p. 4).

Taylor's estimate of rat damage to coconuts in Fiji was, therefore, made by an examination of fruit still on the tree. The writer, on the other hand, estimated rat damage by counting nuts which had fallen to the ground, as well as by Taylor's method. The results differ so strongly from those obtained by Taylor that it is desirable that the figures be published and this alternative method of investigation described.

The extent of the damage done by rats varies considerably in different localities. The writer's principal investigations were made near sea-level on Ura Estate (Taveuni). This is a large estate, and such estates are claimed by Taylor to suffer relatively little rat damage. But in the opinion of the writer, who made comparative notes of the abundance of rat-bored nuts in many parts of Taveuni and other islands, rats were certainly not less in evidence at Ura than in most other places.

At Nabavatu, in Lau, rat-bored nuts were lying about the ground in far greater relative abundance than on Taveuni. But the yield of mature nuts on Nabavatu was, at that time (December, 1933), much reduced, owing to

*Taylor, T. H. C.—"Early Nutfall from Coconut Palms in Fiji," Dept. of Agric. *Bulletin* 17.
Taylor, T. H. C.—"The Possibilities of Controlling Rats on Coconut Estates in Fiji," *Agric. Journal*, Vol. 5, No. 1.
Surridge, H.R.—"The Extermination of the Rat," *Agric. Journal*, Vol. 3, No. 3.

PLATE I.

A—Newly burst spike of coconut palm showing hole bitten by rat through inner spathe, Ura, Taveuni, 1934. Very frequently such damage is associated with exit holes of mature Spathe-Borer larvæ, on which it is suggested that rats may feed.

B—Rat-bored coconuts which fell before they were ripe, Ura, Taveuni, 1934. Note the characteristic ragged-edged holes bored by the rats in order to obtain liquid from the young nuts. These nuts all fell from one tree during a period of one month.

Photographs by R. W. Paine.

past ravages of the Coconut Leaf-Miner; so that the comparative scarcity of mature, undamaged nuts on the ground may have produced an exaggerated impression of the normal rat damage on that estate.

It is interesting to record here, in comparison with Nabavatu, that on Kanacea, an island only twelve miles distant, there are no rats. The present manager of this estate has energetically guarded against the landing of rats from ships calling at Kanacea, and on at least one occasion, succeeded in intercepting would-be colonies brought ashore inside packing cases.

The writer paid three visits to Vunilagi Estate (Vanualevu) during the early part of 1934, and there, fallen rat-bored nuts were found to be as plentiful as at Ura. Taylor's figure for rat damage on Vunilagi in 1929 was 4·17 per cent.; but he says that this was too high a figure for the whole estate, in which the manager estimated rat damage at only 1 per cent. It is possible that more damage is done some years than others. If this is so, one would expect rats to open more coconuts during a dry than during a wet year, since they appear to bore into nuts solely for the liquid contents. But 1933 was a wet year, and rainy weather continued with little interruption for the first six months of 1934, so that the rat damage evident on the occasions of these recent visits is not likely to have been abnormally high. The manager of the estate agreed that rat damage was more severe than he had formerly supposed. These instances of recent personal observations in places outside Taveuni, the number of which could be multiplied considerably, are included to bear out the writer's conviction that the damage done by rats to coconut estates in Fiji is very generally severe, and that the figures appended below, all of which were derived from a two and a half acre block of land on one estate, are representative of many parts of the Colony.

2. Analysis of rat damage on coconut estates.

During the course of eighteen months' field work on coconut estates, it was observed that rats may cause damage to the coconut crop in many different stages of its development. From the time just before the spathe opens until the time any copra produced therefrom is shipped from the estate, damage by rats may take place. The following are the principal ways in which rats may cause damage to this crop.

(i) *Chewing through the inner spathe before the latter bursts* (*cf. Plate* I, *A*).

Taylor remarks on this, but discounts any detrimental effect on the score that only the male flowers are damaged. In 130 youngest spikes from four estates on Taveuni examined by the writer, 42 per cent. of the inner spathes were chewed through in one or more places by rats.

It is true, as Taylor points out, that the rat-borings are usually near the extremity of the spathe; but in a few instances, holes were found near the base, and female flower buds had been damaged.

It was frequently noticed that, although a large portion of the inner spathe had been chewed away by rats, no rat damage could be detected in the flowers lying immediately inside the holes thus made. It was also noticed that rat-chewings were often associated with the round scars made by mature larvæ of *Acrilocera negligens* when emerging from the flowers in a spathe. It is not improbable that rats may feed on these large, fleshy larvæ, and in this way actually play a beneficial part in helping to reduce the numbers of this minor pest. Proof of this hypothesis was not, however, obtained.

The damage done by rats at this stage of a coconut's development is infinitesimal compared with that done later on; but it calls for remark in so far as it provides additional proof of the very widespread occurrnce of rats amongst the trees of a coconut plantation.

(ii) *Damage to the fleshy axillary pads of the lateral flowers branches (spikelets) after the spathe has burst.*

In the 130 spikes already mentioned, 8 per cent. of the spikelets showed stems damaged by rats. The base of a "spikelet" is thickened and composed of soft and juicy tissues. Rats gnaw this part of the flower branch apparently in an effort to obtain moisture. Spikelets badly damaged in this way sag and are unable to support the weight of maturing nuts. It would be difficult to compute exactly the percentage of the crop destroyed in this way; but it would certainly not be more than one per cent.

(iii) *Female flower buds damaged after the spathe bursts.*

Not infrequently, it was found that rats had chewed away a portion or the whole of a young female flower. It appeared that, in the majority of cases, such damage had been inflicted after the spathe had burst open.

For the first few days after opening, the spike contains female flower buds which are comparatively soft and juicy. Rats probably gnaw these, as they do the axillary pads of spikelets, to get moisture.

Although the writer never saw rats in the act of eating young female flowers, there is no doubt that a certain type of injury, not infrequently found in the female flowers on the first open flowering branch is the work of rats. Three per cent. of the female flower buds in the 130 spikes examined bore damage attributable to no cause other than gnawing by rats; and the total damage inflicted by rats at this stage is certainly represented by not less than 3 per cent. of the female flowers because, in computing that figure, all those flowers which were damaged, or had fallen off from some indeterminable cause, were included as not damaged by rats.

The total amount of damage caused by rats to the flowering spike before that stage of its development at which the fruits set is almost negligible, compared with that which takes place during the later stages of fruit development.

To refer again to the 130 first-flowering branches examined on Taveuni, it was found that on no less than 51 per cent. there were definite traces of rat damage. These spikes were cut from trees growing both near to and far from houses; some near sea-level, and some near the top boundary fence of an estate. They show that rats forage over, even if they do not nest on, at least half of the trees on a plantation.

(iv) *Damage to young fruits.*

Most of the damage done by rats to the coconut crop takes place at the various stages of fruit development between pollination of the female flowers and the final maturing of the fruit. Shortly after the fruit is set, a cavity begins to form inside it, in which nutrient fluid accumulates. Rats bite through young nuts at the base in order to obtain this fluid, and in so doing dislodge them from the tree. In many cases, the husk of a nut is incompletely penetrated before the latter falls to the ground, in which case the rat's thirst remains unslaked, although damage has been done. Rats are thus extravagant drinkers, in so far as coconuts are concerned, wasting by clumsiness or inexperience, much that they could use.

Any nut which, as a result of injury by a rat, falls to the ground before the husk has begun to turn brown, is rendered unfit for harvesting, and these nuts, most of which are completely bored by rats, are common objects in coconut estates on any island in Fiji where rats are established (Plate I, B).

The rather ragged-edged, round holes, either at the side, or more usually near the base of such nuts, are so characteristic that in counting nuts lying on the ground, there is no possibility of mistaking those whose premature fall has been brought about by rats.

Taylor writes, " Rats very rarely attack young nuts. They attack the three-quarter grown nuts chiefly." This is largely true, but it is necessary to qualify, or render more explicit, the phrase " three-quarter grown."

In order to fix the exact position on a tree from which rat-bored nuts had fallen, the writer investigated the progressive growth in size of coconuts picked from a sample tree growing within the two and a half acre block investigated at Ura. The length in inches of the female flower buds or fruits from successive spikes on this tree was as follows:—

Spike.	Size of female flower or fruit.	Colour of husk.
1	$\frac{5}{8}$ x $\frac{7}{8}$ inches	Pale yellow (♂ flowers > $\frac{1}{2}$ off)
2	$1\frac{3}{8}$ x $1\frac{3}{8}$,,	Light green (♂ flowers all off)
3	2 x $1\frac{1}{2}$,,	Dark green.
4	$3\frac{1}{2}$ x 2 ,,	,,
5	$4\frac{3}{4}$ x $2\frac{1}{2}$,,	,,
6	$5\frac{3}{4}$ x $3\frac{1}{4}$,,	,,
7	$6\frac{1}{2}$ x $4\frac{1}{2}$,,	,,
8	$6\frac{1}{2}$ x $5\frac{1}{4}$,,	,,
9–18	±7 x ±6 ,,	,,
19	$7\frac{1}{2}$ x 6 ,,	Pale brown (mature).

In order to check the value of the figures from this tree as being average for the whole area, a nut from the sixth spike of twenty other trees in the same block was measured, and the number of immature open fruit branches (spikes) counted. The average length of the young nut on the sixth spike was found to be $5\frac{3}{4}$ inches (maximum $7\frac{1}{2}$ inches, minimum $4\frac{3}{4}$ inches). This agrees exactly with that of the sixth nut on the above sample tree. The average number of immature spikes was fourteen for twenty trees, so that the sample tree had five more such spikes than the average.

A study of these figures will make it evident that a nut is three-quarters grown in size when it is less than half ripe. In other words, the time taken for a newly-pollinated female flower to grow to full size is only half as long as the time it takes to become mature. Thus, when reading Taylor's statement that rats prefer the three-quarter grown nuts, one must bear in mind that such nuts are really less than half mature, and would occupy about the seventh spike on an average tree.

Although the writer agrees that this stage of nut is very commonly found to have been bored by rats, it was seen at Ura that large numbers of full-grown nuts were bored. Even nuts with the husk beginning to turn brown

were on occasions found to have been bored. A number of the largest rat-bored nuts found on the ground in the experimental block were traced to the following positions on five trees:—

Tree.	Rat-bored nuts fell from spike Nos.	Total No. of green spikes on tree.
1	9, 11 and 12	15
2	9	10
3	8	13
4	7 and 8	12
5	9	12

These nuts had fallen to the ground not more than ten days before the above data concerning them were obtained. It is thus evident that rats may cause immature fruits to fall from a number of successive spikes at any one time.

Out of 1,121 fallen rat-damaged nuts, counted over a period of four successive months, in the test block at Ura, 245 (or about 20 per cent.) were small, thin nuts, less than five inches in length. These fell from some two or three spikes at the most, represented by numbers three to five on the average tree.

Such small nuts were not included in the total of rat-bored nuts used in calculating the percentage damaged, since it is considered that their fall may be offset by a subsequent reduction in normal nutfall. But, once a nut is full sized, it would seem unlikely that its premature fall would result in any great saving of food materials in the tree, and thus not tend to be compensated by any increased amount of fruit later on.

As soon as a nut matures, and the husk turns brown, rat damage ceases; because, even if such a nut is nibbled at by rats, sufficiently to cause it to fall as occasionally happens, it is ripe enough to be used for making copra.

From the information set forth above concerning the spikes from which the maximum size rat-bored nuts fell, it can be calculated that, on an average tree in the test block, *i.e.*, one with fourteen immature, open spikes, rat damage ends on about spike ten. It may, therefore, be concluded that rat-damaged nuts of more than five inches in length are falling each month from each of the spikes between the sixth and tenth, on an average tree in the area under consideration.

It will now be convenient to describe the methods adopted by the writer in procuring the data used in the estimation of rat damage.

An area of land, a little over two and a half acres in extent, surrounding the fence which enclosed the overseer's compound at Ura, was weeded and cleared of all fallen nuts and split husks at the beginning of May, 1934.

At the beginning of each of the four subsequent months, the fallen nuts were again examined and counted over this area.

Apart from the nuts which fell prematurely and yet bore no evidence of rat damage, all the nuts lying on the ground were counted, irrespective of size. These consisted of rat-damaged nuts and mature nuts, none of which had been removed from the test area before their numbers were checked by the writer at the end of the month.

As has already been explained, the rat-damaged nuts were divided into two groups; viz., those whose length was less than five inches, and those whose length was greater than this. All nuts which could be cut for copra

were classed as " mature," even if they bore evidence of rat damage.

The figures obtained were as follows:—

TABLE I.

Rat damage at Ura, Taveuni. Estimated by counting nuts on the ground in an area of 2½ acres (143 palms):—

Months in 1934.	Rat damaged nuts.		Mature nuts.	Total nuts 5 inch or more in length.
	Less than 5 inch in length.	5 inch or more in length.		
May	99	278	957	1,235
June	82	261	464	725
July	27	165	373	538
August	37	172	376	548
Totals	245	876	2,170	3,046
Average per month . .	61·2	219	542·5	762·5

These figures show that in a period of four months, during which 51·71 inches of rain fell—twenty inches more than the average for the previous five years—876 large nuts fell prematurely owing to rat damage, and 2,170 fell in a sufficiently mature condition to be harvested.

The estimation from these figures of that percentage of the potential crop which was destroyed by rats is a simple matter, because it is quite justifiable to assume that every large rat-damaged nut found on the ground would have matured in the absence of rats. Thus, for each month of the four during which observations were made, an average of 219 potentially mature nuts were prematurely destroyed by rats. During the same period, it was found that an average of 542·5 mature nuts had fallen per month.

Now the number of mature nuts falling between May and August is probably higher than at other times of the year; moreover, the number of nuts bored by rats during that period in 1934 is not likely to be more than at other times of the year, because the rainfall was unusually heavy, and rats are thought to bore more nuts in dry weather. Therefore, it is estimated rat damage at a conservative figure to assume that a monthly average of 542·5 mature, and 219 rat-damaged nuts, are falling all the year round.

It is thus evident that the potential monthly crop in the absence of rats is 542·5 plus 219 nuts for 143 palms in the two and a half acre experimental plot under review. Therefore, out of a potential crop of 761·5 nuts, 219 are destroyed by rats. This represents a loss amounting to 28·76 per cent. The discrepancy of over 20 per cent. between the figure for rat damage given by Taylor and that derived from the writer's more recent investigations is sufficiently large to demand the closest scrutiny of the methods employed. The writer would, in fact, be very reluctant to publish such a figure as representative of rat damage in Fiji were it not for the fact that he obtained other supporting data by the same method as that employed by Taylor, with which to check the results.

It might be objected that rat damage over such an area as that chosen, which was near to sea-level and to human habitation, is likely to be misleadingly high if the figure is claimed to represent rat damage all over an average Taveuni estate. But in the light of the following information derived from diverse situations in four widely separated localities, such an objection cannot be entertained.

In the investigation of *Tirathaba* damage, carried out by the writer in August and September, 1934, counts were made of the young nuts on branch IV, and of the nature muts on the last six branches of 100 palms in four localities. The information obtained, which has a bearing on the subject of rat damage is set forth in the following table:—

TABLE II.

Rat damage to young coconuts in Fiji, as estimated by counts of nuts on the palm:—

Locality.	Approx. height in feet above sea-level.	Approx. distance from nearest house.	No. of trees examined.	Average height of trees examined.	Average No. of young nuts on branch IV.	Average No. of mature nuts per branch on last six branches†	Percentage of crop damaged by rats.	Percentage of youngest spikes showing evidence of rat damage.
	ft.			ft.				
Ura	150	100 yds	40	38	7·74	3·87	42·6	63
Vuna ..	150	¾ mile	22	46	6·80	3·67	46·0	59
Nalele ..	400	½ mile	17	38	7·27	4·91	31·1	41
Nacaugai ..	10	⅓ mile	21	49	5·06	3·41	32·6	10
*Average (for Taveuni) ..	Various	Various	100	42	6·47	3·96	38·07	43
Taylor's figures for Fiji as a whole, 1929	Various	Various	460	40	4,365	4·066	6·85	..
Taylor's figures for average of 3 estates on Taveuni, 1929 ..	Various	Various	60	40	6·07	5·66	5·11	..

In ascertaining the figures for Branch IV, the writer followed the method adopted by Taylor of excluding all spikes with more than ten young nuts.

* It is assumed, in working out these average figures for Taveuni, that the same number of palms were examined in each locality; it being considered the the number examined in each locality was sufficiently large to provide representative figures for that locality.

† The writer included scars where mature nuts had fallen, as well as the nuts actually remaining on the palm. Taylor may not have done this; but when he made his counts (March–May), more ripe nuts would be on the palms than is usually the case later in the season (August–September), when the writer made counts.

In counting the nuts on the last six branches, the writer included those mature nuts which had fallen off, as well as those remaining on the tree. Taylor does not state whether, in counting mature nuts, he included those which had already fallen; but it is important to emphasise that the writer's estimate of mature nuts is a maximum estimate. The counting of young nuts remaining on branch IV is a simple matter, allowing no scope for error through variation of the personal factor. So that the figures for rat damage derived in this way in 1934 are strictly comparable with those derived by Taylor in 1929. The discrepancy in the results can only be accounted for by supposing either that rat damage has increased very considerably during the last few years, or else that there is a very great seasonal variation in the extent of rat damage, and that Taylor's figure in April for mature nuts from spikes which would have been subject to rat attack from about the previous

October to February, is not strictly comparable with those obtained by the writer in August for mature nuts on spikes which would have been attacked by rats from February to June.

Quite possibly it may be found that rats have seasonal migrations to and from palms in Fiji, and that it would be necessary to carry observations over a period of at least a year in order to make an accurate estimate of the damage which they cause.

But, with the support of the very high percentage figures for rat damage on Taveuni shown in Table II, derived by Taylor's method of counting nuts on the tree, the writer has no hesitation in presenting the figure of 28 per cent. as a minimum for rat damage from May to August, derived from a count of nuts which have actually fallen to the ground.

(v) *Damage to copra after harvesting.*

Rats swarmed over the " vatas " (copra drying trays) at Ura. The writer is unable to supply any figures showing the extent of damage to copra during the progress of drying and storage before shipment; but chewed pieces of copra with tooth marks of rats are in sufficient abundance on vatas to indicate that rat damage to the crop at this stage of its development is far from negligible

3. Total damage caused by rats.

In the previous section it has been shown that rats damage the coconut crop in at least four stages of its development, viz.:—

(i) before the spathe bursts;
(ii) after the spathe bursts, but before the fruit has set;
(iii) after the fruit is set, but before it is mature;
(iv) after harvesting—during the drying and storage of copra.

The damage brought about in stages (i) and (ii) is not more than of the order of 1 per cent. of the crop—the exact figure being impossible to estimate without further extensive investigation. The damage occasioned in stage (iii) is that most easily computed, and is shown to be about 30 per cent.

The writer would not be surprised to learn that over 5 per cent. of the copra is destroyed by rats during the time it lies on vatas and in sheds awaiting shipment from the plantation.

There is obviously scope for further statistical investigations of rat damage. The damage done one month may well be less extensive than that done in another. But from the figure obtained, and the field observations made on Taveuni, it appears likely that at present rats are destroying something like one-third of the total potential copra crop at various stages in its preparation.

4. Conclusion.

Rat damage to coconuts in Fiji has, in the past been greatly underestimated, or else it has become very much more severe than it was five or more years ago.

From being a serious minor pest of coconuts, rats are shown by the writer's recent investigation on Taveuni to belong to the status of a major pest of this crop.

With copra at its present market value, it is perhaps inopportune to attempt control of this pest, but when times improve, the question of rat destruction should be given earnest attention.

At present, little is known concerning the bionomics of the rats which inhabit coconut plantations in Fiji, and this matter requires early investigation. The only approved methods of control which suggest themselves as being practicable under Fiji conditions are trapping and poisoning.

The satisfactory prosecution of either of these methods entails a considerable recurring expenditure, and it would appear not improbable that with the aid of a thorough knowledge of their habits, some more economical and thorough method might be discovered of destroying rats in coconut plantations.

The available information already at hand suggests that rats may be governed in their feeding habits by climatic factors; and it would appear possible that with the provision of some alternatives in the way of food supply, sources of moisture, nesting sites and so forth, rats might be induced to forsake coconut palms and satisfy their appetites in some way other than by the wholesale destruction of young coconuts.

COPRA DRIERS.

(Extract from *The Malayan Agricultural Journal*, July, 1932.)

EXPERIMENTS WITH SMALL KILNS IN KUALA SELANGOR.

Two small-holders were selected by the Malay Agricultural Assistant, Kuala Selangor, for special instruction and assistance in copra manufacture.

The objects of the experiments were as follows—

(1) To demonstrate that good copra could be made on small inexpensive kilns.

(2) To determine what response was forthcoming from the small-holder.

(3) To ascertain what marketing difficulties were to be expected.

Work was commenced in August 1931 and by February 1932, one producer was in a position to make copra of No. 1 quality.

SCHEME 1.

A Javanese small-holder, a man of some wealth and the owner of 20 acres of mature coconuts, was persuaded to rebuild his crude kiln, using brick and iron as materials of construction. The kiln, when completed, was too large for his own requirements, since his annual crop amounted to only one-ninth of the kiln capacity, and so when the production of good dry copra had become an accomplished fact, it was decided to push the scheme a stage further. The owner was accordingly persuaded by the Malay Agricultural Assistant to assist his countrymen and incidentally to reduce his own overhead charges by extending his business. The kiln owner, in turn, persuaded twelve of his neighbours, owning between them some 60 acres of mature coconuts, to consider two alternatives, either—

(*a*) to sell all their nuts to him, or

(*b*) to allow him to manufacture copra for them on commission.

The first alternative was chosen, so leaving the kiln owner the sole responsibility of manufacturer and marketing, and incidentally, giving him a satisfactorily large quantity of copra for him to approach a large dealer.

THE PURCHASE OF CONTRIBUTORS' NUTS.

His method of nut purchase allowed for fluctuations in the price of nuts and for seasonal variations in the ratio of nuts required to make a picul of copra. An example may be quoted—

January 1931—

235 nuts = 1 picul of copra.

Therefore 100 nuts = ·42 picul of copra.

Hence with good dry copra (*i.e.*, "sundried") fetching $6.75 (Singapore) and say $5.75 locally, the copra value of 100 nuts was ·42 × 5·57 = $2.32.

From this, he deducted a manufacturing commission of 30—35 cents per 100 nuts, so leaving a balance of about $2.00 which he paid to his contributors. This is equivalent to a price of 20 cents for 10 nuts.

COMPETITION FROM MIDDLEMAN PRODUCERS.

The response on the part of the middlemen producers was to advance the price of nuts by approximately 30 per cent in order to undermine the loyalty of this unwelcome organisation and pressure was also brought to bear on the dealer who bought the copra from the owner of the new kiln.

Owing to the high quality of the copra he produced, the Javanese manufacturer was always able to pay 2 cents per 10 nuts in excess of the middlemen's top price while the intimidation of the dealer was stopped and his continued support secured as a result of the efforts of the District Officer, Kuala Selangor.

The exceptionally high price offered for nuts attracted considerable attention to this man's work, so that after the first month, no further difficulty was experienced in obtaining sufficient nuts to keep his kiln in continuous operation.

SCHEME 2.

A Malay small-holder, the owner of one of the eight crude kilns, previously referred to, was easily persuaded to build a small kiln of improved design, since his first efforts on his own kiln gave a product which was almost unmarketable.

His resources did not permit of the expense of brick and iron construction and instead clay, coconut timber and attap were used.

Some difficulty was experienced, initially, in persuading the owner to follow a satisfactory method of production, but ultimately he was able to produce copra which was better than average middleman's copra. Since, however, he could not obtain top price, he was unable to offer a high price for nuts and so could not attract regular contributors to his kiln, which was of sufficient capacity to deal with the crop of at least three average-sized small holdings.

THE EFFECT OF THESE EXPERIMENTS.

On Copra Production.

The most outstanding and direct result of these endeavours is that the number of kilns owned by Malays in Jeram has increased progressively, thus—

August, 1930	..	..	6
November, 1930	..	..	30
August, 1931	..	..	35
February, 1932	..	..	120

It cannot be claimed that all these Malay producers are manufacturing good dry copra; in fact, the converse has definitely been stated by an important dealer, viz., that "Malay-produced copra is, in general, much inferior to middlemen producers copra, bad as that is!"

This is due to the fact that at present, effective supervision is impossible and that under existing conditions, individual or group education cannot be undertaken. Whatever progress has already been made is the result of imitation, and lacks the corrective of close criticism.

This indicates that, without adequate instruction, the copra received is likely to be of very mixed quality and that an ambitious large-scale organisation for co-operative marketing of their produce would involve complicated dealings, if profit is to be justly apportioned, and additional expense, on account of the necessity for redrying and grading the product before sale.

On Copra Prices.

Originally and with similar Singapore prices, a standard price of $4.00 per picul was offered for the " wet " low-grade copra produced on the six crude Malay-owned kilns.

The Javanese producer is now obtaining $5.75 for his dry " Sundried " copra, the Malay $5.00 for his dry " mixed " copra, while the imitating Malay small-holders are obtaining between $4.40 and $4.80 for their " wet " low-grade copra.

On Nuts Sale.

These two small schemes have resulted in a similar general improvement and whereas originally 1 cent and 1.4 cents per nut was recorded for " tied " and " free " growers, the price now offered is about 1.4 cents and 1.8 cents respectively, while the Javanese producer, in an unassailable position, is able to offer 2 cents and still prosper.

Further to prove this contention, the case of the near-by District of Kuala Langat may be quoted, since in September 1930 the position as regards nut prices here was the same as in Jeram. A condition of almost general indebtedness is understood to exist and copra production by the small-holder has not yet been inaugurated. The nut prices are now approximately 1.2 cents for " tied " and 1.5 cents for " free " sellers respectively, while the dry low-grade copra of the middleman producer is valued at only $4.65 per picul, equivalent to $4.20 for undried or " wet " low-grade copra.

STATEMENT TO ILLUSTRATE THE IMPROVED FINANCIAL CIRCUMSTANCES OF THE SMALL-HOLDER WHO MAKES COPRA.

Basis.—" Sundried copra = $6.75 per picul (Singapore).

Note.—The Singapore copra prices in September, 1930 and February, 1932 are comparable, but local nut prices have since improved as a result of competition.

Estimated net annual income	By Nut Sale.			By Copra Manufacture.				By other sources.
	To middleman producer.			To Javanese.	Using own nuts and making on own kiln.		Using own & bought nuts.	
	Sept. 1930		Feb 1932	Feb. 1932.				
	If in debt	If free.	If free.	By contributors.	Bad Copra.	Good Copra.	Good Copra.	
	$	$	$	$	$	$	$	$
Javánese owner of mature 20 acre holding.	..	590	..	..	710	935	1,195	..
Malayan owner of good 6 ½ acre holding.	150	210	235	300	310	355	..	..
Dealer in good dry copra above (commission).	..	..	..	..	..	..	..	324
Cooly, employed by Javanese above (wages).	..	..	..	..	..	..	..	163

CONCLUSIONS.

(1) It has been shown that increased education of Malay small-holders in improved methods of copra production where conditions are favourable can succeed.

(2) It is essential that capital must be forthcoming either from a single individual or from a small group of neighbours who are prepared to work together.

(3) Only dry copra of good quality must be manufactured so that a sufficient margin of additional profit is available to put the producer in an unassailable position.

(4) If the kiln has a single owner, he must be fair-dealing and his contributors should preferably be men who are free of debt and are hence unassailable.

(5) Finally, a satisfactory price must be obtained for the improved copra. If a local dealer willing to pay a fair price is not to be found, it will be necessary to go further and organise transport of the copra to larger buyers.

RECOMMENDATIONS FOR THE CONSTRUCTION OF SMOKE KILNS FOR USE BY SMALL-HOLDERS.

General.

The copra-drying platform should be at least 6 feet from the fires, while the fires and the copra should be completely shielded.

An economic small unit would therefore be a closed chamber 6 feet high, 6 feet long and 6 feet wide, entirely surrounded by a large attap shed sufficiently large to provide space for shell fuel, finished copra and working room.

Consideration of Size.

If all the sides of such a square kiln are extended equally, the capital cost per square foot of drying space decreases thus:—

Kiln.	*Drying area.*	*Length of 6 feet walls.*	*Relative cost per sq. foot of drying area.*
6 feet × 6 feet × 6 feet	36 sq. feet	24 feet	·666
12 feet × 12 feet × 6 feet	144 sq. feet	48 feet	·333
15 feet × 15 feet × 6 feet	225 sq. feet	60 feet	·266

If two of the sides are extended so as to give an oblong kiln, the relative cost per square foot of drying area increases. The advantage of greater convenience, however, outweighs this consideration, in the case of large estate kilns.

Since conditions in small holdings normally do not allow of large scale manufacture, only two types of kiln need be considered—

(A) 6 feet × 6 feet × 6 feet or nearest.
(B) 12 feet × 12 feet × 6 feet.

Capacity.

The former (A) is intended for individual small holdings from 6 acres up to 20 acres in extent; the latter for larger small holdings, or for use by groups of contributory small holdings. Allowing for fluctuations in crop, which may frequently vary as widely as 3: 1 or even more, and for careful production, by which only a thin bed of copra is dried at a time, kiln B should easily be able to cope with the crop from 80 mature acres of good yielding coconuts.

The normal provision on estates lies between ¾ square foot of drying area per acre (which is much too little) and 2 square feet per acre (which is correct), so that Kiln B has a recommended outside limit of about 100 acres. At 20 nuts per square foot, its correct working load is 2,800 nuts every four days.

Details of Construction of the Kiln.

1. Especially if the kiln is to be in continuous use, the walls must be designed to retain heat and radiate it uniformly. Hence galvanised iron and attap are unsatisfactory materials for the kiln walls.

2. With kiln B in discontinuous operation, a 9-inch brick wall was decided upon, but for larger kilns in regular and continuous use 15-inch walls, although more costly, will retain more heat and so lead to greater clean heat utilisation and more uniform drying.

3. Walls constructed of heavy alluvial clay have not proved entirely satisfactory, since unless constant attention is given to re-luting the cracks as they appear, the excessive shrinkage of clay will lead to the ultimate collapse of the walls.

Where, however, the local clay is of lighter texture and contains a suitable proportion of sand (*e.g.*, Kuala Langat District), clay may be rammed on to a core of woven sticks and if planks are used to shape and build up the walls, a satisfactory kiln will result.

Normally, binding agents are necessary to prevent the formation of large cracks, while a mixture composed of about 80 per cent. heavy clay, 10 per cent. sand, and 10 per cent. local lime has, after puddling together, resulted in a most solid wall.

Recommended binding agents are—long dry "lallang" grass, string or broken rope, and if the mass is well rammed, padi husk. The core of the wall may be composed of platted sticks, light expanded metal, chicken wire or stacked coconut husks.

The materials to be recommended in any one district naturally depend on local conditions, but undoubtedly brick construction will give more permanent service and is to be recommended wherever its use is possible.

4. Trenches 9 inches deep, excavated in the earth of the fire-pit have been found helpful in arranging and shielding the shell fires from draughts.

5. It has been stated that the large kiln may not always be working to full capacity, and it is therefore essential that provision should be made against the eventuality of lean harvests by providing a cross-wall in the fire-pit to extend from the ground up to the copra platform so that, if desired, only one-half of the kiln may be used without any detriment to the copra by reason of irregular drying.

Uprights in the fire-pits should be of brick, angle iron, iron pipe or stout timber protected by tin plates, otherwise there is a danger of fire.

6. Iron as a material of construction for the copra platform is good, but will account for quite half of the total capital expenditure. Nibong or bamboo slats are not so permanent nor yet so tidy, and an alternative of wooden laths screwed to stout cross beams is to be tried. In all cases it is strongly recommended that local scrap yards should be inspected before the purchase of any steel work.

7. The copra should be shielded from draughts by means of a brickwork rim, 15 inches high, surrounding the copra platform. Alternatives are planks, baulks of timber, or flattened galvanised iron, reinforced by a wooden framework. These have the advantage of portability.

8. A shed to enclose the kiln proper is necessary to screen the kiln from draughts, so that humid air over the copra is kept warm and is unable to deposit its moisture on the topmost copra. By maintaining warm conditions it also increases the heat efficiency, but there must be free escape through the roof for the saturated air, otherwise stagnant conditions will arise, and drying may even be locally suspended to the detriment of the copra.

9. The shed may also serve as a store for copra, for shell fuel and for unripe fruits which need to be matured. Shutters should be provided if the shed is too dark and secure doors are advisable.

10. If a high piece of land is chosen, an excavation some 1 to 2 feet below ground level will bring the drying platform conveniently nearer the ground and will also provide better heat retention and radiation. Alternatively, the ground surrounding the kiln may be built up some 2 feet.

11. No ventilation holes need be made in the walls of the fire-pit, but some provisions is advisable for smoke escape. In Kiln B the height of the girders allowed for a 2-inch gap between the copra and the top of the brickwork. Alternatively, a small gap can be left on the kiln platform between the copra and the copra screens.

ENTOMOLOGICAL NOTES.

By R. W. Paine, Coconut Entomologist.

E.K.E.

SHOT-HOLE BORER IN COCONUTS.

Serious damage to the trunk of a coconut tree at Nabuono Estate, Taveuni, was shown to me by Mr. G. Garrick in September, 1933,

The insect causing the damage was one of those tiny, hard-backed beetles—popularly known in Fiji as "woggs"—which belong to the family of bark-boring beetles *Scolytidæ* ("Shot-Hole Borers").

Mr. Garrick informed me that he has seen the tiny bore-holes of this insect in coconuts before, but that no serious damage had been done because a gummy substance exuded by the tree had blocked up the mines of the beetle and prevented their exit.

The tree I examined was seriously damaged by the beetle because a caterpillar, which feeds on rotting wood, had bored extensively into the outer part of the trunk and ventilated the galleries of the shot-hole borer, which had bred in the tree and was present in large numbers.

Specimens of the beetle were sent to the British Museum for determination, and they belong to the species *Xyleborus perforans*, Woll., recorded from coconuts in Jamaica, where it is not considered to be a serious pest.

XXII 66

No other instance of this insect attacking coconuts has come to my notice in Fiji and it is certainly not a serious pest in this country.

SHOT-HOLE BORER IN AVOCADO.

Of very different economic status from the above is the Scolytid which bores the stems of avocado pears. This insect was noticed on Taveuni in 1931; but comparatively few trees were at that time being grown.

XXI 6

In 1933 my attention was called to a planting of avocados at Waitavala Estate (Taveuni), where extensive shot-hole borer damage was found.

The insect bores into thin, green branches as well as the larger, woody stems, and it is in the former that it does most damage. The entrance hole of the beetle becomes covered by a white, powdery substance exuded by the tree, so that it is quite easy to see where the beetles have gone in.

The damage done to the vascular tissue in the young stems causes them to die back from the tip, the leaves withering. On one or two trees the damage appeared to be so severe as likely to cause the death of the tree.

Specimens of the insect were determined at the British Museum as *Xyleborus morstatti*, Haged. This insect is a serious pest on coffee in East Africa, the East Indies and Ceylon. The material sent from Taveuni in August, 1933, was the first received by the British Museum from the Pacific, and the first from avocado.

The insect appears to be a native of East Africa, where it is not known as a pest. It would seem probable that it is kept in check there by natural enemies.

During the last three years avocado pears have been extensively planted on Taveuni, where they do very well. *Xyleborus morstatti*, therefore, is likely to prove a somewhat serious pest and warrants close attention. Parasites might be sought for in East Africa if the avocado crop were of sufficient importance to justify the expense of their importation.

E.K.G., B. MOSQUITO CONTROL IN COCONUT PLANTATIONS.

The day-biting, filarial-carrying mosquito, *Aedes scutellaris* (*variegatus*), var. *pseudoscutellaris*, Theob., is sufficiently objectionable in coconut plantations in Fiji to warrant the serious attention of an entomologist.

This mosquito breeds mainly in the piles of cut coconut husks left behind by copra cutters on estates where the husks are not burnt. It also breeds in rat-bored nuts, which, of course, are never collected, but accumulate on the ground and hold water for many months after they fall from the tree.

At Ura (Taveuni), where I lived for rather more than a year in the middle of a coconut estate, this mosquito was so numerous as to constitute a serious nuisance when one remained out of doors for more than a few minutes in the same place. At Vuna plantation the mosquitos were very decidedly worse than at Ura.

It has been maintained by Dr. P. A. Buxton, who studied *Aedes pseudoscutellaris* in Samoa, that "It may easily be banished, or nearly banished, from houses by clearing bush away, draining a few of the nearest tree-holes, and collecting the nearest coconut shells, &c." (*Researches in Polynesia and Melanesia*," Parts I–IV, p. 109. Research Memoir of the London School of Hygiene and Tropical Medicine).

I thought that by removing all the coconut husks within fifty yards around the house day-biting mosquitos would no longer be troublesome. Not only was the land kept clean weeded and all the husks (rat-bored included) removed at the end of each month from May to August (1934), but a careful search was made for other breeding places of *Aedes* in and around the house, and the few that were found were destroyed.

Tests made to show the effect of these attempts at control gave results more convincing, that is the memory of one's own personal experience. The tests were made by collecting all the mosquitos which bit me whilst seated

for fifteen minutes, firstly inside the compound, and then outside the husk-freed area. The following figures were obtained:—

Date.	Time.	Weather.	Mosquitos collected.	
			By house.	Outside cleared area.
1934.				
7 May	8.40	S.E. strong	1	10
	16.35	S.E. moderate	2	34
9 May	8.30	Calm; sunny	4	26
15 May	8.45	Calm	6	16
26 May	8.35	Calm; drizzle	11	22
4 June	8.30	Calm; sunny	15	28
13 June	8.50	N. light; sunny	7	40
30 June	8.55	S.E. light; sunny ..	2	24
21 July	9.10	Calm; sunny	2	56
Totals	...	.....	50	256

It is quite clear from these figures that *Aedes* was very much more abundant outside than inside the cleared area; but the absolute value of the experiment cannot be ascertained, except in purely an empirical way, because I omitted to carry out control observations before the test area was cleared, But to be biten by even as few as six mosquitoes in fifteen minutes, which is the average number for the test situation in the instances just quoted, is sufficiently annoying to make one hesitate in recommending removal of husks, &c., for only 50 yards round a house in order to produce complete control of day-biting mosquitoes.

In a northerly wind *Aedes pseudoscutellaris* is always much more abundant than in a southerly, and I feel fairly certain that many of those which entered the house flew from breeding places more than 50 yards away and lodged in trees with heavy foliage near the house.

On some plantations the husks are systematically burnt after the copra cutters have finished with them. This practice cannot be too highly commended from the point of view of mosquito control.

On Nacaugai Estate I spent several hours seated in the plantation examining coconut flowers. I saw only two mosquitos. At Vuna, where a similar time was spent on the same occupation it was not only necessary to wear extra clothing to protect myself from the hordes of mosquitos, but fires had to be lighted to smoke them out so that I and two Fijian assistants could carry out our work.

Rat-bored husks cannot be burnt, and as *Aedes* breeds in these the complete control of these mosquitos on a coconut plantation is a difficult matter to carry out.

ACRITOCERA NEGLIGENS. Butl.

Mr. G. F. C. Taylor, Coconut Entomologist, records that eggs of this spathe-boring moth are, in Lau, parasitised by some, at present unknown, Chalcid.

VETERINARY NOTES.

By C. R. Turbet, B.V.Sc., Senior Veterinary Officer.

HOW TO GIVE A HORSE PHYSIC BALL (PILL).

The occasion sometimes arises when it is necessary to administer medicine to horses. Should it be desirable, either on account of the nature of the medicine or for convenience sake, to give it in a solid form a " pill " or in horse language a " ball " is made.

The giving of a ball to a horse is an art, but few people possess it. Horse owners, however, should know how to give a ball, since the method is an easy and convenient one. It would be folly to attempt for the first time, to give a horse a ball containing an evil tasting or an irritant medicine, since, without practice, failure to administer the ball effectively is common and results in the horse chewing the ball and thus tasting the contents. The result is that the animal will resent any further efforts to administer a ball. It is desirable, therefore, to make several dummy balls, containing sweet tasty materials, using soap or dough as a base, and with these to practice the art of " balling "

Failure in giving the dummy ball will not be resented by the horse and he will then not object to the real thing. The would-be physician should not attempt to give the medicinal ball until he feels confident, through practice, that he can do the job properly.

If bran is available a bran mash should be given in the evening, no other food being allowed. On the following morning water may be given before adminstering the ball. It might be mentioned that with the old fashioned ball, the paper surrounding it should be lubricated with saliva.

To give the ball satisfactorily one person should stand on the left side of the head facing forward and with both hands help to hold the mouth open at the critical moment. The operator giving the ball stands facing the horse with the right shoulder in line with the centre of the horse's face. He takes the tongue in the left hand with fingers uppermost and thumb beneath. Then the tip of the tongue is turned upwards and to the operator's left, so that it protrudes at the right side of the horse's mouth, whilst the thumb moves towards the right side of the roof of the mouth. Then holding the moistened ball with three fingers of the right hand, thumb and little finger being tucked underneath, pass the hand swiftly and neatly back over the tongue and deposit the ball well back at the entrance of the throat. The same instant release the tongue, allow the mouth to close and push the head up. If this is done correctly the animal should automatically swallow the ball. The ball can be observed passing down the gullet on the left or near side of the neck. If it is not observed to pass down give the horse a small whisk of grass to eat. The ball will then be carried down in the swallow.

REPORT ON BANANA DISEASE INVESTIGATIONS, 1933.

By B. E. V. Parham, M.A., Assistant Agricultural Officer.

Introduction: Scope of Report.

The present report comprises a brief statement of the nature and progress of work undertaken during 1933 in connection with the investigation of banana diseases, particularly that commonly referred to as "Sigatoka" or "Leaf-spot" disease.

2. In addition to the monthly reports the following reports have been submitted in the course of this work:—

(1) Progress Report, March to June, 1933.
(2) Report on Waidina Areas, July, 1933.
(3) Progress Report, September, 1933.
(4) Scheme of Work, October, 1933.

Staff and Material Available.

3. Arriving in the Colony on 10th March, the writer proceeded to Navuso Experimental Station on the 14th March, so that the work described below refers to the following period of nine and a half months only. Owing to staff limitations an actual total period of 140 days was available for banana work, the balance being devoted to general work at Navuso Experimental Station. For six weeks during August and September the part-time assistance of Mr. M. Dods was available and is gratefully acknowledged.

4. For purposes of field experimental work there were already in existence at Navuso about seven acres of bananas:—

Block I.—Three acres; five rows each of Veimama, Gros Michel and Cavendish.
Block II.—Four acres; seven rows each of above varieties.
Block III.—One acre; each Veimama and Cavendish, planted October, 1932.

5. The first two were heavily infected with "Leaf-spot" disease and a proportion of the plants were also showing signs of "Bunchy-top" virus disease.

6. Block III was selected for the purposes of experimental tests in spray and manurial treatments. Subsequently it was decided to destroy Blocks I and II, at the same time using the plants for record purposes.

7. During the year two new areas were opened up and planted and three small nurseries established.

8. No external field trials of any kind were attempted as it was felt that these could be deferred until a survey of the main banana areas had been completed and field conditions were better known.

9. Through the activity of the Agricultural Officer and his native agricultural assistants new areas were planted at Nawaqabena on the Waidina and at Serea, Korovatu and Vunidakua on the Wainimala, and preliminary arrangements made for the planting of a specially selected area (under instruction and observation) at Yauvoli in the vicinity of Viria. The history of these plantations being known adds to the value of future observations.

10. Both at Navuso and in the field generally the work has benefited greatly from the constant co-operation and advice of the Agricultural Officer.

Summary of the Situation, March, 1933.

11. A review of the available records covering the past twenty years indicates that during that period the most troublesome diseases and pests of the banana have been:—

"Sigatoka" or "Leaf-spot" disease.
Bunchy Top.
Weevil Borer (*Cosmopolites sordidus*).
Scab Moth (*Nacoleia octasema*).

Of these, the first-named has proved the most virulent, restricting the growth of the plant and preventing the proper maturation of the fruit.

12. Since 1931 this disease has become increasingly evident in the plantations being now very widely distributed and a serious menace to profitable banana cultivation.

13. During 1932 it was estimated (Council Paper No. 27, 1933) that heavy rejections, amounting to about 40 per cent. of the fruit offered for shipment, took place at packing stations owing to the ravages of this disease. Based on the value of the year's exports this loss represented a sum of £60,000 potential return.

14. In the same year certain preliminary spraying and manurial experiments at Navuso Experimental Station had given no certain results and reports from Queensland (Simmonds, J. H., *Queensland Journ. Agric.*, Vol. 39, 1933), where an identical disease was reported, indicated a similar failure to control the trouble in the field.

15. The cause of the disease had been ascribed by Massee, Knowles and Campbell in Fiji and by Simmonds in Queensland to a leaf-spotting fungus (*Cercospora musæ*, Zimm.) owing to the constant association of this organism with the condition. The degree of pathenogenicity of *Cercospora musæ* has not, however, been established by means of inoculation and reisolation tests.

Aim and Scope of Work attempted.

(*a*) Field Observations.

16. As a properly equipped laboratory was not available for the necessary intensive study of the organisms associated with the disease of the banana, attention was almost wholly directed towards field observations and experiments with a view to—

(i) investigating some of the suggestions and theories concerning the cause of the disease and the falling off of banana production;
(ii) obtaining information as to the nature and regional occurrence of the disease;
(iii) exploring the possibility of control in the field by various methods of plant protection.

17. Many of the views held locally as to the causes affecting susceptibility of the banana were not in agreement and had not been put to the test of scientific inquiry and observation. Among these may be enumerated:—Borer infestation, soil deficiency, locality, lack of shade, cultivation, and drainage. This part of the work has involved the careful recording of the following data:—

(1) The incidence of the disease and its effect upon the growing plant at all stages, the rate of leaf and root development and of leaf infection.
(2) The effect upon development of fruit thrown and its ripening characteristics.

(3) Types of leaf spotting organisms and their effect on different varieties of bananas.
(4) The physiological requirements of the banana plant and its reaction to varying environment.
(5) Relationship between borer infestation and leaf infection.
(6) The effect of bunchy-top on the plant system and the means of adequate destruction of diseased stools.
(7) Season, varietal and regional variations in the incidence of disease.
(8) Fungi causing rots of ripe fruit. Some of these make their first appearance in the plantation and are intimately concerned in the premature ripening and wastage of fruit.

(*b*) Field Experiments.

18. The following field experiments have been instituted and carried out at Navuso Experimental Station.

1. Direct Control of Leaf-spotting Organisms.

19. (*a*) *Spraying.*—A series of spraying tests were planned and carried out as follows. Each plot containing eight stools of which individual records were kept:—

Plot.
A—Copper Sulphate Ammonia (*Eau celeste*).
B—Boiled Linseed Oil and soft soap emulsion.
C—Burgundy mixture 4–5–50.
D—Control. Untreated.
E—Burgundy mixture 4–5–100.
F—Coconut Oil and soft soap emulsion.
G—Modified *Eau celeste.*
H—Raw Linseed Oil and soft soap emulsion.
J—Burgundy mixture 4–5–50 and molasses.
K—Burgundy mixture and Sodium Resinate soap.
L—Bouisol, normal strength.
M—Sulsol, normal strength.

20. The coconut and linseed oil sprays and the *Eau celeste* and modified *Eau celeste* solutions were included at the suggestion of the Government Chemist who also provided the Sodium Resinate for Plot K. Duplicate plots were treated in both Veimama and Cavendish areas. The choice of spraying materials was governed by the following considerations:—

(1) cost and local availability;
(2) ease of preparation and application, particularly with reference to the possible use by native growers;
(3) capacity for spreading and "sticking" to surface of banana leaf.

The fungicidal properties of the oil sprays were unknown.

21. (*b*) *Stripping.*—Stripping, or the complete removal of all infected leaves, was carried out at intervals over the whole plantation, as well as in connection with the spraying and manurial treatments. In the latter case half the stools in each plot were so treated.

22. (*c*) *Sucker sterilisation.*—The problem of preventing the spread of disease in planting material has been investigated. Between 400 and 500 suckers, eyes or "bits" were treated with Formalin 1 per cent. and Burgundy Mixture 4–5–50 for varying periods. These were then placed in nurseries for observation prior to planting out. The growth of these treated plants has been good, but final results are not available.

23. (*d*) *Soil sterilisation.*—With the aim of exploring the possibility of soil fungi affecting the health of plants (as suggested by the high proportion of root rots) certain preliminary tests were made. For the purpose, Cavendish suckers, planted in tubs of soil partially sterilised by treatment with Cheshunt Compound and with Formalin, were compared with comparable suckers planted in untreated soil.

2. Indirect Control of Disease.

24. (*a*) *Manurial.*—The manurial plots of six stools each were treated as follows:—

Plot.		*Per acre.*
I	Muriate of Potash	1 cwt.
II	Superphosphate	2 ,,
III	Phosphate	4 ,,
IV	Muriate of Potash	2 ,,
V	Muriate of Potash	4 ,,
VI	Superphosphate	8 ,,
VII	Superphosphate and Potash	1 and 2 cwt.
VIII	Control	No treatment.
IX	Muriate of Potash and Superphosphate ..	2 and 4 cwt.
X	Muriate of Potash and Superphosphate ..	4 and 8 cwt.
XI	Coral sand	5 tons.
XII	Boron. 1 oz., Boracic Acid per 4 galls. water.	

The above refers to the Veimama plots. Cavendish plots were treated similarly with the addition of three extra plots which had applications of—

Super	(2)	Mur. of Potash	(1)	and Sulp. of Ammonia	(1)
,,	(4)	,,	(2)	,,	(2)
,,	(8)	,,	(4)	,,	(4)

Plots I to X were treated in June and October, Plot XI in November and Plot XII in December.

25. (*b*) *Interplanting.*—The possibility of utilising non-susceptible varieties of *Musa* spp. such as Blue Java, Lady's Finger and certain plantains, as biological barriers has been studied by the interplanting of rows of these varieties with the commercial susceptible "China" bananas. Not only might this method of planting be of use in checking the spread of wind-borne diseases but also it is hoped to obtain therefrom definite information as to the means by which the disease is spread, the relative susceptibility of local varieties, the factors associated with immunity, and the effect of soil. The use of *Gliricidia maculata* as a wind barrier and shade tree is being investigated.

26. (*c*) *Crop rotation.*—A method of crop rotation involving the limiting of production to one plant crop only, the spacing of the rows in such a way as to permit the use of green manures and cover crops and the continued use of the same land has been advocated in the West Indies as a favourable means of combating disease and conserving the fertility of the soil. A small area at Navuso was planted along these lines.

27. (*d*) *Planting material.*—The choice of planting material, the relative merits of suckers, eyes, bits, and the pre-treatment of these for control of borer and fungal disease are factors which have received careful attention. There is no doubt that a great deal of trouble in the plantations can be traced to the lack of attention to the planting material used.

(*c*) Laboratory and Special Investigations.

28. A laboratory for mycological work was built during the year, but the requisite apparatus was not available until December. This part of the work was, therefore, limited to general studies and to some microscopical investigation of various organisms associated with disease in the banana, and to the behaviour of diseased and normal fruit ripened at ordinary tropical temperatures. The trapping and hand-picking of borer was undertaken in order to discover the effect on population of season and rainfall, the stage at which traps are most effective and the cost of daily trapping per unit area. Various methods controlling scab moth were used in the experimental plots.

Results of Work Attempted.

29. The results of the preliminary work outlined above may be briefly stated. These are obviously incomplete owing to the short time period and also to seasonal variations and to lack of continuity due to staff and labour limitations.

(*a*) Field Observations.

30. These have been based on records made during the survey of banana plantations as well as at Navuso Experimental Station, where the various plots have been under constant close observation. Field trips included visits of inspection to the following places:—

(1) Waidina River as far as Namosi.
(2) Island of Viwa.
(3) Tailevu province, Namara district and Bau Island.
(4) Tailevu province as far as Wailotua.
(5) Lower Rewa.
(6) Waidoi River.
(7) Nabukavesi.
(8) Waidaleci River, Tailevu.
(9) Towns of Viria, Nawaqabeqa, Lomai and Natodre.
(10) Packing stations at Rukuruku and Tausa, three times.

1. Incidence of "Leaf-spot."

31. *Regional.*—Throughout the areas inspected this disease is present, in many places to a marked degree even in comparatively recent plantations, and in the case of older stands, generally affecting all the plants.

32. The area of bananas rendered unproductive by the ravages of the disease is difficult to estimate. In many districts it exceeds that as yet free from disease, that is, on a conservative basis, the areas at present occupied by unproductive plantations are probably not less than those still producing marketable fruit. Thes represents the annual loss of a potential crop valued at £90,000 at current prices. The present quota system masks the significance of the facts to a great extent and obscures the actual situation. In view of the proposed extension of the industry in the direction of new markets in Canada, the actual position in the field cannot be regarded as satisfactory. When it is realised that many of the existing plantations are of comparatively recent origin, being planted since the hurricanes and floods of 1930 and 1931, the extremely adverse influence of this disease as a crop limiting factor cannot fail to be recognised.

33. *Individual.*—"Sigatoka" disease affects the plant at all stages. Symptoms are best seen in the destruction of leaf surface and the morbid condition of the pseudostem and rooting system. Leaf infection is rapid, becoming evident to the naked eye in transmitted light as small brown flecks, between two and three weeks after the leaf is unfurled. Thereafter the pro-

gress of leaf necrosis is so rapid that the whole leaf is involved and usually no more than three clean leaves per plant can be counted. There is thus a continuous abnormal destruction of leaves during the whole life of the plant, and when the bunch is thrown , the rapid failure of the final leaves results in practically complete defoliation before the fruit has reached maturity. The bunch either fails to develop normally or if it reaches the three-quarter stage, individual fruits begin to ripen prematurely, and on being broken across, the green fruit shows characteristic colour and other symptoms. Very frequently during ripening at tropical temperatures, very rapid main-stalk and cushion rots set in and these hasten the premature colouring and maturation of the fruit.

34. The rooting systems of infected plants are found to be severely reduced and such roots as remain are in a highly morbid state, contrasting markedly with the tough white roots of healthy plants. Root hairs are wanting and the state of the rooting system suggests a constant endeavour on the part of the plant to grow new roots. The corm is often variously discoloured and the pseudostem is rendered unhealthy by the persistence of the dead and decaying leaf bases. In many cases these are subject to bacterial rots, and, commonly, fructifications of *Marasmius* sp. may be found occurring at all heights from the ground level up to the crown of the plant.

35. *Seasonal.*—Commencing in March, 1933, complete detailed records were kept of the progress of the disease in 182 main plants and some 400 suckers of Veimama, and in 270 main plants and 500 suckers of Cavendish variety. A noticeable improvement in growth and in leaf condition during the months May, June and July was succeeded by a rapid falling off in September and October, at which time the majority of plants under observation began to throw their first bunches. This increase in the visible effect of the disease was remarked coincidentally in other plantations of comparable age which had not been subjected to the operations of cultivation, spraying and manuring of the Navuso plots.

36. *Varietal.*—As far as the observed plots were concerned, no varietal differences were evident, Veimama and Cavendish exhibiting the effects of the disease to a similar degree. From field records it is evident that the Veimama variety is generally preferred and in some areas no other variety is grown. There is insufficient evidence that this variety, or any of its several strains, is less susceptible than the others. Cavendish grown in favourable situations is capable of equally robust growth and the production of excellent bunches. Gros Michel is reputedly the most susceptible variety, but several stands of this variety have been seen quite healthy and bearing well.

37. There is every indication that under prevailing conditions of available land for planting and incidence of disease, not even one ratoon crop can be expected with any certainty in any but the best soils.

38. Varieties of bananas, such as Blue Java, Lady's Finger, and certain plantain varieties exhibit marked qualities of immunity and have consequently been exploited in the prosecution of the present investigations.

2. Relation of Borer to Leaf-spot.

39. In the course of the removal of Blocks I and II at Navuso 340 stools, heavily infected with "Sigatoka" disease were specifically recorded with the following results:—

Variety and No. of plants.	Average leaf infection per plant.			Percentage on borer attack.			Percentage on root decay.	
	Clean.	Light.	Heavy.	Clean.	Light.	Heavy.	Light.	Heavy.
Veimama (98) ..	1½	2	2	43	35	22	12½	87½
Cavendish	2	2	3	37	33	30	13	87
Gros Michel (126) ..	1	2	1	31	37	32	4	96

Note:—Normal plants often carry 7 or 8 clean leaves, with a total of 13 or more standing leaves.

40. Additional data have been secured from Block III at Navuso and these give added grounds for the conclusion that there is no direct correlation between the degree of infection by "Leaf-spot" and the incidence of borer. The plants recorded above as light borer infested were so slightly damaged by this insect that normal physiological functions of the plant could have been affected but little. On the other hand, of 40 Cavendish plants examined suffering from bunchy top, 4 were found free of borer, 12 with light borer attack and 24 heavily infested. It remains to be determined whether borer is a primary agent in these cases or whether it is attracted to those plants already in a morbid condition from the ravages of the virus disease.

3. Soil Deficiency.

41. As a preliminary to this part of the work, soil samples have been secured each month from the banana areas at Navuso and from many localities visited in the course of field survey. These have been submitted to the Government Chemist for analysis and report.

42. Experimentally, a commencement was made with the growing of Cavendish bananas in tubs of soil secured from various localities, in ordinary alluvial soils of Navuso and soil with a high humus content ("Adco" compost material). Although there has been considerable variation in the response of the plants already started, results are necessarily incomplete at this stage.

43. The effect of manurial treatment is discussed below.

44. *General.*—The subject of banana soils is beyond the scope of the present report, other than with reference to their effect on the growth of the plant in relation to disease. From the writer's observations the following facts emerge:—

(i) that the banana plant is not, as frequently supposed, capable of normal robust growth in all types of soil, but is on the contrary, rather particular in its soil requirements;

(ii) that at the present time, extensive areas of land entirely unsuitable for the purpose are under bananas;

(iii) that many areas at one time capable of carrying heavy crops of bananas have been rendered infertile by the practice of long period single crop cultivation, by the consequent progressive reduction of the humus content of the soil from this cause and from denudation by heavy rains;

(iv) that many of the alluvial flats are, in their present condition unsuitable, for bananas either on account of lack of drainage, mechanical condition of the soil or low humus content and that bananas planted on such flats are particularly liable to early heavy infection of leaf spot disease;

(v) that the most suitable available soil for bananas appears to be, on the mainland, the well-drained virgin or reinstated "forest" soils normally supporting heavy jungle vegetation;

(vi) that plantations on the red clay and soapstone soils (excepting those which weather to a black coloured soil) are usually of very short duration;

(vii) that there is urgent need for the introduction of some system of re-conditioning suitable areas by means of proper methods of fallow, crop rotation, cover crops and green manuring, as a means towards both the conservation of the humus content and the elimination of disease.

4. Location.

45. The aspect seems to have little bearing on the incidence of disease, but a considerable amount of shade and shelter from winds appears to be beneficial to healthy growth. In many localities this is automatically achieved by the choice of new areas generally protected by strips of jungle.

46. Experiments have been begun at Navuso with the growing of shelter belts of *Gliricidia maculata*, a leguminous tree, which may also be used with benefit as a green mulch for bananas.

5. Cultivation.

47. The effect of clean cultivation and tillage has been variously estimated. Locally, many hold the view that the prevalence of disease is directly due to these factors, citing as examples the plantations of Chinese and Indian cultivators, which are notoroiusly subject to heavy infection. The Fijian, on the other hand, avoids clean cultivation, merely cutting back the undergrowth of weeds, shrubs and creepers between the plants. Under the latter conditions the banana roots are found to extend long distances, actually on the surafce of the soil or only slightly buried, but even so, these plantations are not always less susceptible to disease.

48. At Navuso the experimental area was kept weeded and the soil cultivated to a depth of a few inches, and only rarely was it found that these operations injured any roots. The area available was not large enough to permit comparative treatment by other methods. It has been noted that the banana plant is tolerant only of certain types of undergrowth and is adversely affected by the in-coming of such grasses and weeds which form a close mat on the ground surface. In this connection Thurston Grass *Paspalum conjugatum* is probably the most undesirable. Undergrowth such as Mile-a-Minute (*Micania scandens*) Kau Moce (*Cassia spp.*), Sila (*Croix lachrymarum*) and even Para Grass (*Panicum barbinode*) seemingly having little adverse effect on the growth of bananas.

6. Drainage.

49. Although a moisture-loving plant, the banana is intolerable of excess of water at the roots, requiring a well drained soil as a first necessity. The majority of the roots are lateral ones not penetrating to a depth greater than one or two feet, although certain vertical roots have been followed at Navuso to a depth of eight feet.

50. The susceptibility of plants to disease has been found to be in close correlation with the water relations of the roots as affecting the turgidity of the plant tissues. The condition most favourable to fungal infection is that caused by lack of water supply and this is effected by drought or by killing of the rootlets and root hairs by excess of water or by other causes. Thus the mechanical condition of the soil may have an important bearing on the disease-resisting capacity of the plant.

7. Packing Stations.

51. Visits to packing stations gave an opportunity of studying the condition of fruit offered for sale, the methods of handling and the proportion of rejects due to disease.

52. (*a*) *Condition of fruit.*—On several occasions a considerable proportion of the fruit offered was obviously affected by disease, and large rejections were made on account of "Leaf-spot" disease, scab moth and immaturity.

53. Fruit was followed from plantation to packing station. In one case the plants (Cavendish) from which the fruit had been cut that day were found to be almost defoliated by Diamond spot (*Scolecotrichum musæ*) and by another fungus (unidentified). The general appearance was very similar to that produced by "Leaf-spot," but it was found that, with the exception of two over-mature bunches, all the fruit from these plants was accepted, and upon examination proved to be free from the symptoms associated with that condition. This observation, with others, contradicts the theory that premature ripening is due solely to destruction of leaf-surface, and suggests rather that the virulence of "Sigatoka disease" is due to some other cause than mere leaf destruction by *Cercospora musæ*. It was impossible, from reports available, to obtain any detailed information as to the condition of any particular shipment on arrival in New Zealand.

54. (*b*) *Methods of handling.*—The Veimama and Cavendish varieties are very subject to bruising and fungal waste, and even with careful handling mechanical injury cannot be avoided.

55. The inaccessibility of many native plantations at the present time results in the fruit receiving very rough handling. Carried in various primitive ways from field to village, and thence by boat or bamboo raft, the fruit often takes up to 48 hours to reach the packing centres, and a further 24 hours or even longer to arrive at the ship's side in Suva.

56. At the packing stations some effort is made to handle the fruit carefully, but much damage is sustained, particularly when the cases are being nailed down. The rots of banana fruits are mainly caused by fungi which gain entry through wounds in the skin or through the damaged stalk end. The banana refuse from previous occasions, which marks most stations, is a potent source of infection, and spores starting under the favourable conditions of tropical temperature and humidity cannot but develop rapidly even in the cooler temperatures of the ship's hold.

57. It has been recommended on the best authority that for overseas shipment, involving transport to any distance, the maximum period between cutting and loading into ship's hold must not exceed 36 hours. Under present conditions this is neither possible nor perhaps necessary, but is a question which would have to be faced should shipment to more distant markets ever become an accomplished fact.

58. Further, there seems little reason why proper grading of fruit should not be carried out more systematically, particularly with regard to the avoidance of packing in the same case fruit at several different stages of maturity. The use of a case nailing machine is suggested as the most satisfactory way to avoid the quite unnecessary damage caused by the present method of nailing down cases. Incidentally the discolouration of cases has been noted to be due in good part to " blue stain " caused by a species of *Ceratostomella*. Much improvement is possible but apparently not sought for.

59. (*c*) *Rejects on account of " Leaf-spot "*.—Rejects on account of "Leaf-spot " disease varied with the season, the locality and the amount of fruit offering, from 5 per cent. to 25 per cent., and on a few occasions there was an oversupply of good fruit. Rejection due to scab moth was heavy, particularly on the Waidina, varying from 5 per cent. to 10 per cent. and more.

(*b*) Field Experiments.

60. (1) *Results of spraying*.—The results of the spraying tests have been affected by the fact that with the unskilled labour available it was impossible to carry out the schedule as planned. Applications were made during the months of May, June, August, November and December as circumstances permitted.

61. None of the spray plots reflected any marked benefit from the applications made, and by the end of the year there was no significant difference between the treated and the control plots.

62. Although for various reasons the spray programme could not be adhered to it is evident that the possibility of the adequate protection of leaf surface by means of liquid fungicides is strictly limited by the following factors:—

(1) The smooth surface of the banana leaf which causes liquids to run off.

(2) Frequent rain showers, which occuring shortly after an application, tend to wash off the fungicide.

(3) The rapid production of new leaves which would require spraying at ten days intervals for effective preventive treatment, and the difficulty of reaching the new leaf before infection has taken place.

63. The following notes were made:—

(i) Burgundy Mixture at both strengths gave a fair " cover," persisted despite subsequent rains and showed at least some temporary effect in checking leaf infection.

(ii) Coconut and Linseed oil with soft soap emulsion spread well, but failed as a fungicide.

(iii) *Eau celeste*, both solutions failed to compare with Burgundy Mixture in spreading capacity and did not check the leaf infection. Leaf burn resulting from this mixture indicates that this material is not suitable for general use.

(iv) Burgundy Mixture with Molasses and with Sodium resinate soap wetted the leaves satisfactorily.

(v) Bouisol and Sulsol (colloidal preparations of Messrs Electro Chemical Processes Ltd., England), particularly the latter, spread well, but were applied too late in the year for results to be effective.

64. (2) *Stripping*.—Consistent stripping on a large scale gave negative results, as also the periodical stripping carried out in conjunction with the spraying and manurial tests. At the same time these operations demonstrated the extreme rapidity of development of the disease as far as the rate of leaf destruction was concerned.

65. (3) *Manurial.*—From the point of view of disease control, the manurial experiments were not successful. The improvement in the growth of the plants and in the colour of foliage being completely negatived by the onset of heavy infection coincident with the commencement of the hot weather.

66. The effect of the manurial applications on the crop cannot be stated as records are not yet complete. By the end of November some large bunches were thrown, but their development was seriously affected by the rapid development of disease.

67. (4) *Soil Sterilisation.*—The results of partial sterilisation are not available. It was found impossible to complete the series, but it is of interest to note that the plants in untreated soil made little progress, were heavily diseased, and one died after four months, being succeeded by a poor sucker. The plants in treated soil grew well, the foliage was of a darker green and although attacked by *Cercospora musæ*, the individual leaves stood much longer than is usual and the pseudostem remained clean and healthy.

68. (5) *Interplanting.*—The site chosen for this plantation was on a hill-slope with a northerly aspect. The land had not been cleared for some years and was covered with the usual secondary jungle vegetation. The land was ploughed and harrowed and planted as follows:—

Row.

1. Blue Java suckers soaked in water 21 days.
2. Plantain, Businimoko, Qamau, Bawa.
3. Plantain, Mami, Baloa, Vudi loaloa, Bawa.
4. Blue Java, suckers soaked 21 days.
5. Plantain, Bawa i tokai, Sauvai.
6. Plantain, Budi ni oba.
7. Blue Java, soaked 21 days.
8. Veimama, untreated.
9. Veimama, suckers soaked 1 hour Burgundy 4–5–50.
10. Blue Java, suckers soaked 21 days in water.
11. Cavendish suckers soaked 1 hour B.M. 4–5–50.
12. Cavendish, untreated.
13. Lady's Finger, and Blue Java.

69. The planting material for this area has been collected as opportunity allowed from numerous localities where possible being specially selected under personal supervision. Owing to this, the area was not completely planted up by the end of the year. The growth of the established plants was very good. With the exception of one or two "Vudi" suckers which succumbed early-on to borer, and one Lady's Finger plant which developed bunchy top, there was no sign of disease up to the end of the period under review. Borer trapping and hand picking was commenced in November.

70. (6) *Crop Rotation.*—The area selected for this experiment was similarly situated to the last. It was only possible to plant partially with specially selected and treated suckers of Gros Michel, Veimama and Cavendish varieties. Growth was good, but no results can be expected for a considerable time as this is essentially a long term experiment.

71. (7) *Planting Material.*—Various types of planting material and several methods of treatment were investigated.

72. The nature of water suckers as compared with "sword suckers" was established. It was found that the former develop the characteristic broad (adult) leaf on account of complete or almost complete severance from the corm of the mother plant. This is often brought about by the ravages of

borer or by mechanical injury. This separation from the mother plant prematurely throws the shoot on its own resources and checks normal development, the young corm has not the same opportunity of food storage, with the result that such suckers do not stand transplanting so well as the sword suckers.

73. The soaking of suckers for 21 days in water prior to planting in order to kill weevil-borer has been reported previously to result in a higher proportion of bunchy top plants. Some evidence in support of this was obtained during the progress of the work.

74. Sections of corms or " bits " were found to give good results when planted out in nurseries. By using such material there is certain less chance of the transference of live borers and diseased plants.

(*c*) Laboratory and Special Investigations.

75. As explained above facilities for this part of the work were not available before the end of the year.

76. A certain amount of preliminary work was, however, accomplished in the way of investigating the various organisms causing disease in the banana.

77. The following organisms have been found associated with diseases of the banana in practically all localities:—

(1) *Cercospora musæ* Zimm. causing destruction of leaves at all stages.

(2) *Cordana* (*Scolecotrichum*) *musæ*, Zimm (" Diamond Spot ") causing in some instances the death of large areas of leaf surface. From observations made it does not appear that this disease affects the behaviour of the fruit.

(3) *Marasmius* sp. causing death and decay of the leaf bases and so involving the pseudostem. Fungi of this type are the cause of serious root diseases of the banana and other economic plants. Fructifications of this fungus are frequently found on Veimama and Cavendish bananas severely affected by " Sigatoka " disease.

(4) *Gloeosporium musarum*.—Infecting flower bracts and green fruit in the plantation, the established cause of destructive fruit rots and particularly associated with abnormal ripening of fruit.

(5) Virus disease, causing bunchy top and destroying the plant or preventing it fruiting.

(6) In addition to the above " leaf speckle " (cause unknown) involving death of leaves particularly is shady situations, a leaf spot caused by an ascomycetous fungus, not yet determined, probably of the family Mycosphærellaceæ, which are all serious plant pathogans, leaf " rust " (not identified) causing heavy destruction of leaves, Bacteria causing collapse and decay of petioles and leaf bases and rots of corm and associated tissues.

78. In connection with these studies comparisons have been made between diseased and healthy plants, root systems have been examined in detail and a considerable amount of material collected and preserved for further detailed study.

79. *Fruit ripening*.—As the most serious manifestation of leaf spot disease is its effect on the fruit, a great deal of attention has been given to the behaviour of fruit from normal and diseased plants. No suitable facilities for the proper storage of fruit being available, these observations have been confined to fruit hung in an open shed at ordinary tropical temperatures.

Four hundred bunches have been so studied. It is possible to give the following general notes:—

(1) In many cases fruit from diseased plants fails to develop and rarely reaches the three-quarter stage in a marketable condition.
(2) Under the conditions of the tests, diseased fruit cut at three-quarter stage ripened irregularly on the bunch, the time taken varying from 4 to 7 days.
(3) Fruit from normal plants took from 10 to 14 days to ripen.
(4) Abnormal ripening was found to be associated with a rapid collapse and decay of the main stalk and with the early development of cushion and finger rots. The careful vaselining of the cut stalk ends failed to prevent this condition.
(5) Many bunches which were harvested at the half stage or thin three-quarter stage failed to ripen at all, the colour changes were absent and decay caused by *Gloeosporium musarum* was always present.
(6) The high proportion of cushion rots suggested that the prevailing practice of stripping the flower bracts prior to dusting for control of scab moth might provide wounds for the entry of fungi. This point was investigated in the field towards the end of the year and results are not available.
(7) Bruises, and all types of damage to the main stalk, to the finger stalks or the individual fruit were found to result in the establishment of organisms of decay and in the accelerated ripening of the fruit.

80. In the course of the work some attention has been given to other diseases and pests including the following:—

81. (1) *Bunchy top.*—The incidence of this disease has been recorded and various methods for the rapid destruction of affected stools have been tried. During the year this disease was reported to be prevalent in the Island of Koro and its presence was noted in all the localities visited. While it does not occur in epiphytotic proportions the poor condition of many plants, particularly of the Cavendish variety, is due to the presence of this disease. Cases were noted at Navuso of young plants which had all the symptoms of bunchy top but which subsequently grew out of that condition.

82. (2) *Borer* (*Cosmopolites sordidus*).—Daily trapping and hand picking was carried out for 144 stools at Navuso with the following results:—

Month.	Total No. of borers.	Rainfall.
January	3,634	7·09 inches.
February	2,402	11·35 ,,
March	2,355	33·57 ,,
April	3,078	33·14 ,,
May	2,398	13·45 ,,
June	2,071	2·72 ,,
July	1,598	4·35 ,,
August	2,129	2·41 ,,
September	2,132	3·09 ,,
October	952	5·16 ,,

83. A record of time taken was kept and the average obtained gives the cost of trapping and hand picking by this method as 30s. per acre per month, based on wages at 2s 6d. per day. Poison traps, involving the use of a mixture of Paris Green and flour were also used. The latter method, which is that in compulsory use in Australia, is preferable to the former on account

of the time saved and the certainty of not introducing the insect with the traps. In the trapping of a new area at Navuso it was found that numbers of borers were being brought in on the stems used for new traps and these probably accounted for some of the noted increase in the catches on the day after new traps were placed.

84. (3) *Scab Moth* (*Nacoliea octasema.*)—This pest is extremely prevalent in some areas, especially on the Waidina River.

85. At Navuso the following steps were taken to control the pest in experimental plots:—

(1) *Dusting.*—This has controlled to some degree the larvæ in later stages, but is not effective for checking primary infestations which occur at a very early stage of development of the flower bud.

(2) On behalf of the Government Entomologist, five colonies of parasites were liberated at Navuso, and Lower Rewa.

(3) *Spraying.*—Flosol was sprayed on to the unopened flower buds, as soon as they became visible. Three or four days later when the bunch was sufficiently open, kerosene emulsion was used to destroy the remaining larvæ. This procedure was very effective, but is not considered capable of wide practical application mainly owing to the danger of scorching the fruit with improperly prepared kerosene emulsion.

Conclusions.

86. Final conclusions are not attempted, but the available information may be summarised as follows:—

(1) " Sigatoka " Disease is a highly virulent disease of bananas, capable of rapid development and spread.

(2) This disease exists throughout the banana growing areas in varying proportions and exerts an adverse influence on the economic production of fruit.

(3) Its effects are seen in the destruction of leaf surface by various leaf spotting fungi, the failure of fruit to mature, the premature ripening of the fruit and decay of the pseudostem and the inhibition of satisfactory ratoon crops.

(4) Practical control of the disease in the field has not been demonstrated possible by means of spraying, nor does it seem that this means of plant protection could be correctly and profitably carried out by native growers.

(5) A great deal of trouble has arisen through the unwise selection of land for planting, the use of diseased and inferior planting material, the continued cultivation of the same land and the universal neglect of ordinary precautions in the way of plant sanitation and protection.

(6) Large areas of completely diseased and abandoned plantations exist in all districts and these serve as infection centres for spreading diseases and pests to new plantations in the vicinity. No effort is made to reduce the sources of infection by judicious cleaning of plantations and destruction of diseased material. The land so occupied by worthless stands of bananas could well be utilised for other crops or else progressively prepared for replanting at some future date.

Recommendations.

87. Arising out of the observations made during the year, the following possible means of control, reduction and eradication of disease in the field are at present available:—

88. (1) *Elimination of sources of infection.*—This involves the systematic and rigorous removal and destruction of diseased plant material. Under Regulation 23 of the Noxious Weeds and Diseases of Plants Ordinance, Section 7, the authority exists for the proper carrying out of this work of plant sanitation. In the writer's opinion this is a work of the first importance, long overdue and essential to the proper re-establishment of the banana plantations.

89. (2) *The rigid selection of planting material.*—There is abundant evidence of the propogation of pests and diseases by the careless selection of suckers. There appers to be little conscious effort on the part of growers to select suckers for planting from robust and healthy stools. Bunchy top and borer particularly being extended in this way.

90. (3) *The search for and propogation of the more resistent varieties and strains.*—This might involve the importation under quarantine conditions of suitable varieties from abroad, and the thorough testing of their behaviour under local conditions, prior to distribution.

91. (4) *Crop rotation and elimination of ratoon crops.*—This method practised by the United Fruit Company has much to commend it from the point of view of combating plant diseases and maintaining soil fertility.

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IN MEMORIAM.

JOHN PAUL TARBY, formerly Manager of the Government Rice Mill, who passed away after a long illness on April 1st, 1934, deeply regretted by his old colleagues.

CONTENTS.